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Undiscovered Locatable Mineral Resources in the Bay Resource Management Plan Area, Southwestern Alaska: A Probabilistic Assessment

Scientific Investigations Report 2007-5039

U.S. Department of the Interior
U.S. Geological Survey

EPA-6363-000002552

Cover: Photograph of historic gold dredge on Wattamuse Creek, a placer gold deposit in the Bay Resource Management Plan area. (Photograph taken by Frederic Wilson, U.S. Geological Survey, 1975.)

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Conversion Factors

Multiply	By	To obtain
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
square kilometer (km^2)	0.3861	square mile (mi^2)
gram (g)	0.03527	ounce, avoirdupois
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8.$$

Undiscovered Locatable Mineral Resources in the Bay Resource Management Plan Area, Southwestern Alaska: A Probabilistic Assessment

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Abstract

The Bay Resource Management Plan (RMP) area in southwestern Alaska, north and northeast of Bristol Bay contains significant potential for undiscovered locatable mineral resources of base and precious metals, in addition to metallic mineral deposits that are already known. A quantitative probabilistic assessment has identified 24 tracts of land that are permissive for 17 mineral deposit model types likely to be explored for within the next 15 years in this region. Commodities we discuss in this report that have potential to occur in the Bay RMP area are Ag, Au, Cr, Cu, Fe, Hg, Mo, Pb, Sn, W, Zn, and platinum-group elements. Geoscience data for the region are sufficient to make quantitative estimates of the number of undiscovered deposits only for porphyry copper, epithermal vein, copper skarn, iron skarn, hot-spring mercury, placer gold, and placer platinum-deposit models. A description of a group of shallow- to intermediate-level intrusion-related gold deposits is combined with grade and tonnage data from 13 deposits of this type to provide a quantitative estimate of undiscovered deposits of this new type.

We estimate that significant resources of Ag, Au, Cu, Fe, Hg, Mo, Pb, and Pt occur in the Bay Resource Management Plan area in these deposit types. At the 10th percentile probability level, the Bay RMP area is estimated to contain 10,067 metric tons silver, 1,485 metric tons gold, 12.66 million metric tons copper, 560 million metric tons iron, 8,100 metric tons mercury, 500,000 metric tons molybdenum, 150 metric tons lead, and 17 metric tons of platinum in undiscovered deposits of the eight quantified deposit types. At the 90th percentile probability level, the Bay RMP area is estimated to contain 89 metric tons silver, 14 metric tons gold, 911,215 metric tons copper, 330,000 metric tons iron, 1 metric ton mercury, 8,600 metric tons molybdenum and 1 metric ton platinum in undiscovered deposits of the eight deposit types.

Other commodities, which may occur in the Bay RMP area, include Cr, Sn, W, Zn, and other platinum-group elements such as Ir, Os, and Pd. We define 13 permissive tracts for 9 additional deposit model types. These are: Besshi- and Cyprus, and Kuroko-volcanogenic massive sulfides, hot spring gold, low sulfide gold veins, Mississippi-Valley Pb-Zn, tin greisen, zinc skarn and Alaskan-type zoned ultramafic platinum-group element deposits. Resources in undiscovered deposits of these nine types have not been quantified, and would be in addition to those in known deposits and the undiscovered resources listed above. Additional mineral resources also may occur in the Bay RMP area in deposit types, which were not considered here.

Introduction

Purpose and Scope

As part of its land planning and management responsibilities, the U.S. Bureau of Land Management (BLM) is producing a series of resource management plans (RMPs) for regions of Alaska in which it oversees Federal lands. The U.S. Geological Survey, under the authority of Interagency Agreement # LAI-05-0020, was asked to provide a quantitative assessment of undiscovered locatable mineral resources for inclusion in the Bay RMP area report. The Bay RMP area encompasses parts of eleven 1:250,000 quadrangles in the southwestern part of Alaska (fig. 1). It stretches from the Alaska Range on the East to Goodnews Bay on the west, and includes Lake Iliamna, the Wood River Mountains, and the headwaters of Bristol Bay (fig. 1).

This report and associated digital files are the summary of that quantitative mineral assessment. This information and additional data on known (discovered) deposits will be incorporated by BLM, into the Mineral Occurrence and Development Potential reports and Reasonably Foreseeable Development alternatives in the RMP process.

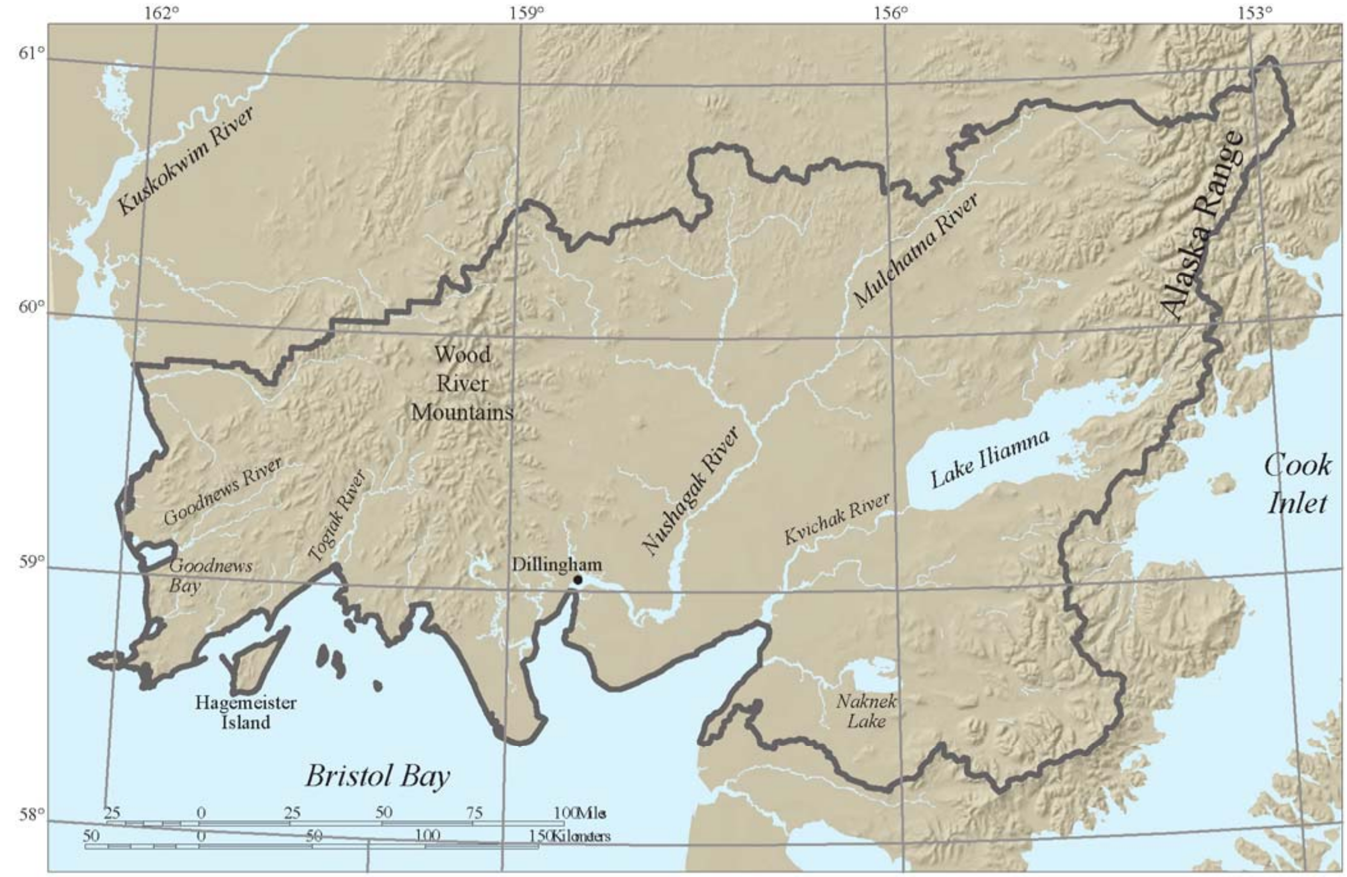

Figure 1. Location of the Bay Resource Management Plan area (inside gray line), Alaska.

Terminology

Throughout this report the term "BMPA" refers to the Bay Resource Management Plan area, as defined and used in the Bureau of Land Management's Resource Management Plan (RMP) process. Other terms used here are modified from USGS assessment language (U.S. Geological Survey, 2000).

A mineral "resource" (or deposit as used in this report) is a concentration of naturally occurring minerals in the Earth's crust of sufficient size and grade that economic extraction of a commodity from that concentration is currently or potentially feasible (U.S. Bureau of Mines and U.S. Geological Survey, 1980). "Undiscovered" mineral resources are previously unknown deposits postulated to exist 1 km or less below the surface of the ground, and incompletely explored mineral occurrences or prospects that could potentially be of a size and grade to be classified as a deposit or resource. The undiscovered category specifically excludes deposits already known at the time of the assessment. Undiscovered resources include those expected to be similar in type or model to known deposits (hypothetical), and those in favorable geologic settings but of uncertain type or model (speculative).

A "permissive" tract is an area within which, using current information, geologic conditions existed that would permit the formation of deposits of a particular model type. Conversely, areas outside of permissive tracts have a negligible (<1 in 100,000) chance of containing a deposit of a given model type, assuming that the geologic conditions known today are accurate, and the deposit model adequately describes the conditions under which mineralization forms.

A "descriptive model" is a set of information that describes a group of mineral deposits that have similar geologic, mineralogical, and geochemical characteristics. A "grade and tonnage model" is a series of frequency distributions and associations of grades and sizes constructed from data from well explored, often mined, individual mineral deposits of a given type. "EMINERS" is a software program (Duval, 2004) that is used to estimate the metal endowments of specific commodities by combining grades, tonnages, and number of deposit estimates at those same probabilities.

Probabilistic Assessment Methodology

The methodology used for this Bay RMP area study was the three-part assessment commonly used by the U.S. Geological Survey and other entities for mineral assessments (Singer, 1993; Drew and others, 1999). In the first part of the assessment, tracts are delineated as permissive for the occurrence of specific mineral deposit types (models) based on similar geological variables (host rocks, structural setting, etc.) in the study area. In the second part, grade and tonnage models are selected that best reflect the descriptive mineral-deposit models selected and that are consistent with known deposits and occurrences in and near the area being assessed. These grade and tonnage models describe the distributions of grades (metal contents) and sizes of known examples of the deposit model, and therefore indicate the grades and tonnages likely to occur in the area being assessed.

The third part of the assessment estimates the number of undiscovered deposits of each type, consistent with the descriptive and grade and tonnage models. Mineral deposits known to exist within the tract at the time the assessment is carried out are specifically excluded from inclusion in these "undiscovered" estimates. Each estimate is made such that approximately one-half of the estimated number of undiscovered deposits have tonnages larger than the median tonnage, and such that one-half of the grades in the undiscovered deposits are greater than the median grade in the grade and tonnage model identified for the deposit type. The quantitative estimates produced here for the Bay RMP area indicate the likely number of undiscovered deposits of a median grade and median tonnage for the deposit model in question, at the 90th, 50th and 10th percentile levels. Uncertainties in the estimates are accounted for by the spread in number of deposits between the 90th and 10th percentile (probability) levels. Estimates of the number of deposits are based on several factors, including (1) evaluation of deposit densities from well-explored areas of similar geology (Singer and others, 2001), (2) extrapolation from known deposits or the frequency of related deposit types in the region, (3) identifying geochemical anomalies of elements associated with the deposit type, (4) identifying areas of similar geologic settings or processes to known deposits in or near the region, (5) identifying geophysical signatures similar to those of the deposit model, and (6) statistical guides of the range of uncertainties in the distribution of data that can result in a given mean number of deposits (Singer, 1993, 1994; Singer and Menzie, 2005).

Following the three-part assessment, a simulation analysis was used to estimate the total mineral endowment (metal content) represented by undiscovered deposits of each type. Probability distributions for the total contained mineralized rock and metals are estimated using the USGS EMINERS software program (Duval, 2004), derived from a Monte Carlo simulator designed by Root and others (1992). The EMINERS program uses piecewise linear approximations of the number of deposits and the tonnages and grades of metals in the simulations to avoid the effects of high values due to skewed probability distributions. A random number generator is used to sample distributions similar to the grade and tonnage distributions for each deposit type and estimate of number of deposits. The simulation randomly samples the distributions 4,999 times and calculates an estimate of the contained metals expected in the undiscovered deposits.

This three-part assessment methodology yields results that include probabilistic expressions of uncertainty. To emphasize the extent of this uncertainty, results reported here include the 95th and 5th percentiles (probabilities) for contained metals, in addition to estimated mean values. The 95th percentile probability indicates 19 in 20 chances, while the 5th percentile level refers to a 1 in 20 chance that the amounts shown will be at least that large. The 95th and 5th percentiles are considered reasonable minimum and maximum values, and the mean is the average, or expected value.

Undiscovered Mineral Resources in the Bay RMP Area

For the Bay RMP area, an expert panel was convened in Anchorage (November 15–16, 2005) to carry out a quantitative assessment of undiscovered locatable mineral resources using all available published and unpublished geologic, geophysical, geochemical, and mineral occurrence information. This panel (L. Drew, T.D. Light, M.L. Miller, R. Saltus, J. M., Schmidt, and F.H. Wilson), with input from B.M. Gamble and A. Schulz, determined which mineral deposit models would be included in the assessment and delineated all permissive tracts. We included in this assessment only deposit model types that we judged were reasonably likely to be actively explored for or developed in the BMPA region within the next 15 years. Using this criterion, permissive tracts were identified for 17 mineral deposit models (table 1); 24 tracts permissive for those deposit types were outlined.

Table 1. Permissive mineral deposit tracts within the Bay Resource Management Plan area.

[**Deposit model:** From Cox and Singer, 1986. **Abbreviations:** BC-AK, British Columbia-Alaska. Au, gold; Ag, silver; An, anorthite; Cu, Copper; Hg, mercury; Mo, molybdenum; Pb, lead; PGE, Platinum-group elements; Pt, platinum; Zn, zinc. gpt, gram per metric ton; km², square kilometer; ppb, parts per billion; %, percent; mt, metric ton; NA, not estimated]

Tract identification No.	Area (km²)	Deposit type	Deposit model	Estimated number of median deposits at three probability levels: 90	50	10	Mean number of undiscovered deposits	Median tonnage (mt)	Median grade
		Deposit models for which quantitative estimates were made							
BCAK	37,480	Porphyry Cu, BC-AK type	17.1	3	6	17	8.1	86	0.37% Cu, 0.0025% Mo
CUSK1	11,020	Copper (Au) skarn	18b	1	2	10	4.1	0.56	1.7% Cu
CUSK2	1,950	Copper (Au) skarn	18b	No estimate made			NA		
EPIV	43,470	Epithermal vein, generic	25d	3	7	20	9.5	0.3	6 gpt Au, 38 gpt Ag
FESK1	11,020	Iron Skarn	18d	1	2	10	4.1	7.2	50.0% Fe
FESK2	1,950	Iron Skarn	18d	No estimate made			NA		
HG	47,570	Mercury	27a	1	2	5	2.5	0.0095	0.35% Hg
IRG-SIL	42,260	Intrusion-Related Gold (shallow to intermediate level)	New	0	1	5	1.9	15	1 gpt Au
PGEP	11,770	Placer PGE (Au)	39b	3	7	20	9.5	0.11	2,500 ppb Pt
PLACER1	55,350	Placer Au	39a	1	2	7	3.1	1.1	0.2 gpt Au
PLACER2	15,260	Placer Au	39a	No estimate made			NA		
		Deposit models for which no quantitative estimates were made							
BESSHI	15,970	Besshi massive sulfide	24b	No estimate made			NA		
CYPRUS	5,060	Cyprus massive sulfide	24a	No estimate made			NA		
HSAU	43,470	Hot spring gold		No estimate made			NA		
KUROKO1	6,650	Kuroko massive sulfide	28a	No estimate made			NA		
KUROKO2	10,290	Kuroko massive sulfide	28a	No estimate made			NA		
LOSAU	6,600	Low-sulfide Au-quartz veins	36a	No estimate made			NA		
MVT	1,720	Mississippi Valley Type Pb-Zn and Kipshi Cu-Pb-Zn	32a, 32b, 32c	No estimate made			NA		
SNG	36,120	Sn Greisen	15c	No estimate made			NA		
ZNSK1	11,020	Zinc (lead) skarn	18c	No estimate made			NA		
ZNSK2	1,950	Zinc (lead) skarn	18c	No estimate made			NA		
ZUM1	6,600	Alaskan (Zoned Ultra-mafic Complex) PGE	9	No estimate made			NA		
ZUM2	2,720	Alaskan (Zoned Ultra-mafic Complex) PGE	9	No estimate made			NA		
ZUM3	900	Alaskan (Zoned Ultra-mafic Complex) PGE	9	No estimate made			NA		

Four members of the panel (Light, Miller, Schmidt, and Wilson) determined for which tracts an appropriate grade and tonnage model, and adequate geologic information was available. Both features were required to estimate the number of undiscovered deposits within a tract. The four panel members made quantitative estimates of undiscovered deposits for 8 of the 24 permissive tracts outlined. L. Drew provided guidance on use of the probability tables and expected value calculations, and along with J. Duval (USGS retired) modified the published EMINERS program for use in the Bay RMP area. T.D. Light carried out the final runs of the EMINERS program. Commodities for which some quantitative estimates were made are: Ag, Au, Cu, Fe, Hg, Mo, and the platinum-group elements (PGEs) Ir, Os, Pd, and Pt. Commodities assessed as permissive, but not quantified are Cr, Pb, Sn, W, and Zn.

Probabilistic Assessment of Tracts for Deposit Models with Quantitative Estimates

Tract Name: BCAK

Model Name: Porphyry copper (BC-AK type)
USGS Deposit Model: 17.1
Area: 37,480 km²
Mean undiscovered deposits: 8.1

Rationale for Model Choice and Tract Delineation

The eastern portion of the BMPA is permissive for porphyry copper (Cox, 1986c), BC-AK type porphyry copper (Menzie and Singer, 1993), and porphyry copper-molybdenum (Cox, 1986d) deposits.

Tract BCAK (fig. 2) is defined by the occurrence of Jurassic, Cretaceous, and Tertiary stocks and plutons of intermediate to felsic composition (Detterman and Reed, 1980; Nelson and others, 1983; Riehle and others, 1993; Decker and others, 1994; Wilson and others, 2003; F.H. Wilson, U.S. Geological Survey, unpub. data, 2006) that are exposed at relatively deep erosional levels. These stocks and plutons occur in a broad belt that includes the Alaska and Aleutian Ranges in the eastern part of the BMPA and lowlands and hills west of the range front. The western boundary of the tract was delineated based on regional aeromagnetic data, to encompass a large magnetic domain in the southeast part of the BMPA. This domain is characterized by abundant short wavelength, high amplitude magnetic anomalies, most likely caused by magnetite-bearing intrusive rocks at relatively shallow depths in the subsurface. Oxidized (magnetite-bearing) intermediate- to felsic- composition plutons are commonly associated with porphyry copper systems (Cox, 1986c). Tract BCAK also is characterized by high K/Th ratios where aeroradiometric data are available. The high K/Th values indicate the presence of felsic rocks, including granitic plutons, which may be hosts or causative intrusions for porphyry copper deposits.

Permissive tract BCAK includes a number of known deposits and several occurrences of the porphyry copper type (Young and others, 1997), and is actively undergoing porphyry exploration. Most reported occurrences contain molybdenum and/or gold in addition to copper. Grade and geologic information from most prospects is insufficient to determine if they are porphyry copper, porphyry copper-gold, or porphyry copper-molybdenum deposit types.

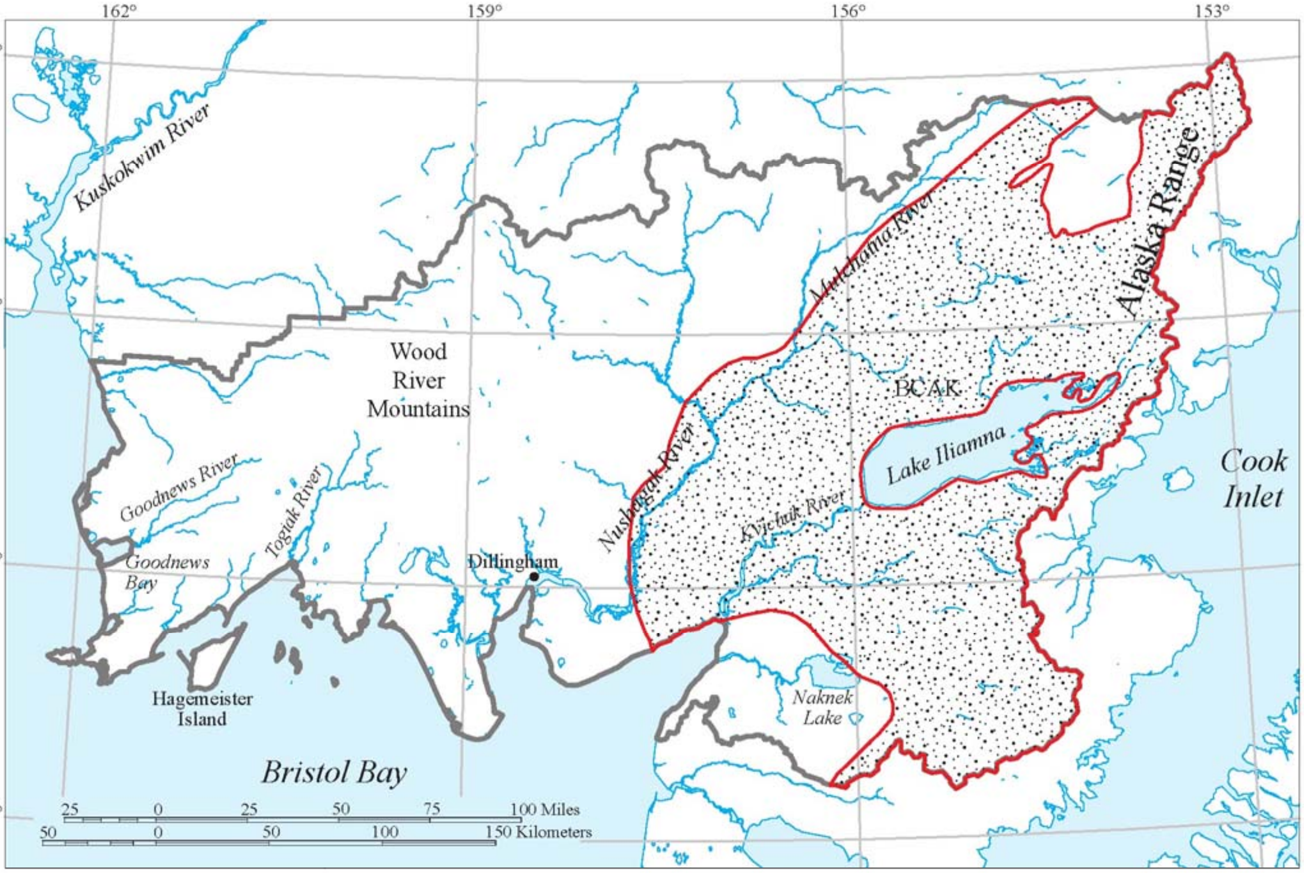

Figure 2. Location of tract BCAK, delineating areas within the Bay RMP area that are permissive for porphyry copper (BC-AK type) deposits.

The Pebble porphyry copper-gold-molybdenum system (Bouley and others, 1995; Schrader, 2001; Tracy, 2001; Hawley, 2004) is the best-known porphyry-type deposit in the BMPA. The Pebble West deposit contains measured and indicated resources of 569 million metric tons of ore grading 0.46 weight percent copper, 0.50 gpt gold, and 0.021 weight percent molybdenum (using a 0.70 weight percent copper-equivalent cutoff grade). The contained metal in those resources was estimated to be 5.8 billion pounds of copper, 9.1 million Troy ounces of gold, and 265 million pounds of molybdenum (Northern Dynasty Minerals, Ltd., 2005). Using the same cutoff grade (0.70 weight percent copper-equivalent), inferred resources from Pebble West and the Pebble East deposit (still under exploration) add an additional 1.75 billion metric tons of mineralized rock with a contained metal estimate of 23.9 billion pounds of copper, 23.1 million Troy ounces of gold, and 1.46 billion pounds of molybdenum (Northern Dynasty Minerals, Ltd., 2006). The Kijik River deposit, which also occurs in tract BCAK, was estimated (without drilling) to contain 91 million metric tons of mineralized rock; grab samples yield up to 0.25 weight percent copper and 0.17 weight percent molybdenum (Bickerstaff, 1998).

Quantitative Estimates

The grade and tonnage model for BC-AK porphyry deposits (model 17.1) was selected for the quantitative estimates because the worldwide model (17) includes some deposits that have large supergene enrichment zones, which are unlikely to occur in Alaskan deposits, and because the BC-AK type includes deposits in geologic conditions more analogous to those in the BMP area. Under the three-part scheme proposed by Cox and Singer (1992) to classify porphyry deposit systems by their gold and molybdenum content, the BC-AK type porphyry copper grade and tonnage model (Menzie and Singer, 1993) used here includes deposits representing all three of their groups.

Additional porphyry copper (±gold ±molybdenum) deposits beyond those currently known that have grades and tonnages within the range of the BC-AK model are likely in this tract. The number of additional deposits likely was estimated based on typical spacing and densities of porphyry-type deposits worldwide, on K/Th ratio similarities, and on the percentage of the tract known to have suitable causative plutonic rocks.

The number of undiscovered porphyry copper deposits, consistent with the grade and tonnage curves of Menzie and Singer (1993) (median 86 million metric tons, 0.37 weight percent copper, 0.0025 weight percent molybdenum), was estimated to be 3 at the 90th percentile, 6 at the 50th percentile and 17 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered porphyry copper deposits within tract BCAK to be 8.1 (table 2). The possible amount of contained metals within the undiscovered deposits at the mean and at five probability levels also is shown in table 2. Figure 3 is a visual representation of the uncertainty in the estimates of contained metal in undiscovered deposits. The histogram shows the proportion of the 4,999 randomly generated simulations that were produced within EMINERS that yielded a given contained metal value. Figure 4 illustrates the cumulative probability of a given tonnage of any metal or mineralized rock. Tables and figures presented for all the quantitatively estimated deposit models in this assessment follow the same format.

Tract BCAK has a 95-percent probability of containing at least 69 million metric tons (Mt) of mineralized rock, and a 5-percent probability of containing as much as 14 Mt copper; 0.66 Mt molybdenum; 850 metric tons gold or 6,200 metric tons silver (table 2; figs. 3 and 4).

Table 2. Estimated amounts of contained metal and mineralized rock (metric tons) in porphyry copper deposits in tract BCAK.

[EMINERS index: 68 (BC-AK porphyry Cu 17.1). Mean number of deposits = 8.1. **Abbreviations:** Cu, copper; Mo, molybdenum; Au, gold; Ag, silver]

Quantile	Cu	Mo	Au	Ag	Rock
0.95	260,000	190	0.1	0	69,000,000
0.90	910,000	8,600	9	48	240,000,000
0.50	4,500,000	140,000	210	1,400	1,300,000,000
0.10	12,000,000	500,000	684	4,900	3,400,000,000
0.05	14,000,000	660,000	850	6,200	3,900,000,000
Mean	5,500,000	210,000	290	2,000	1,600,000,000
Probability of mean	0.41	0.36	0.39	0.37	0.42
Probability of zero	0.03	0.05	0.06	0.09	0.03

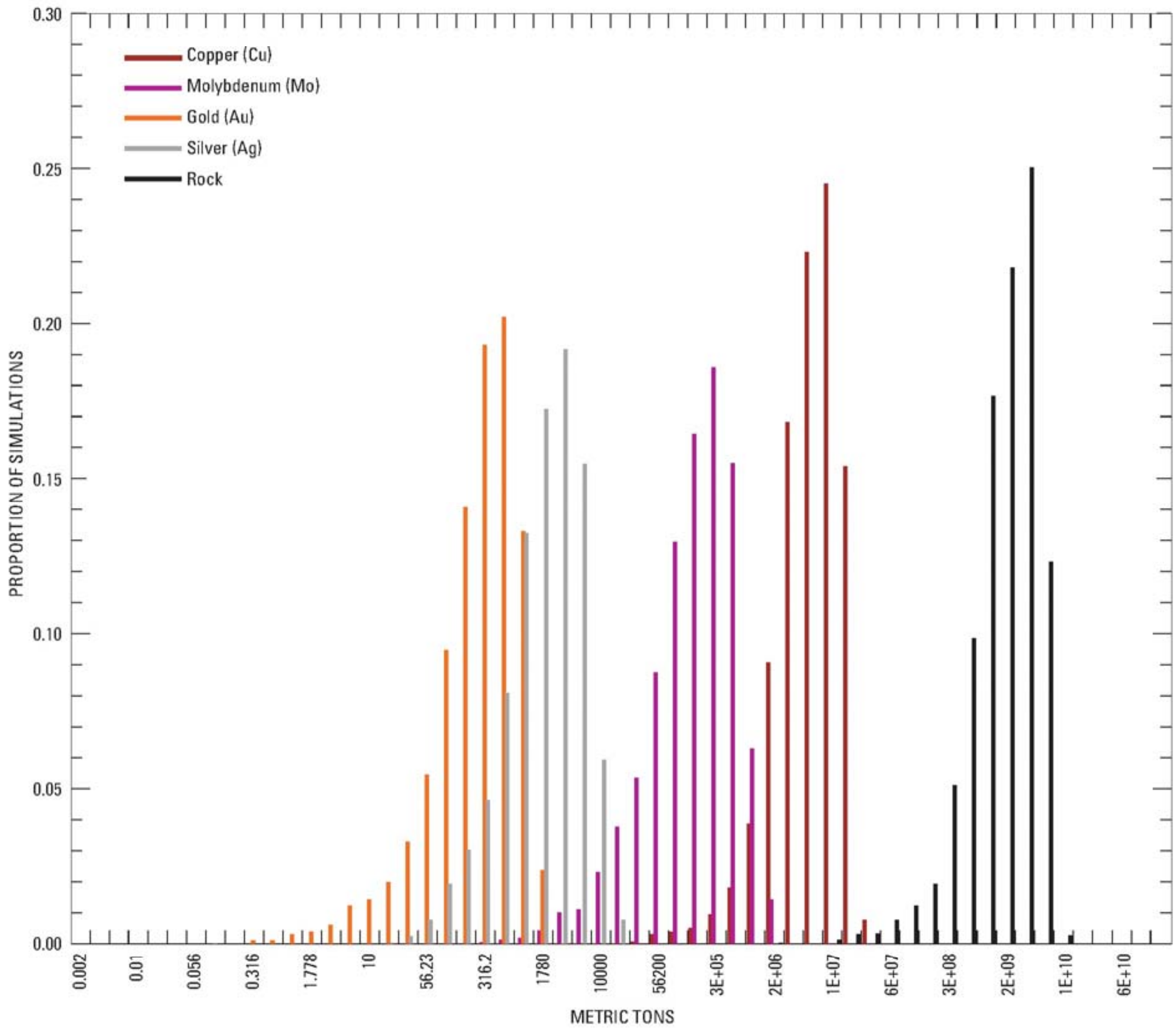

Figure 3. Contained metal and mineralized rock in porphyry copper deposits in tract BCAK.

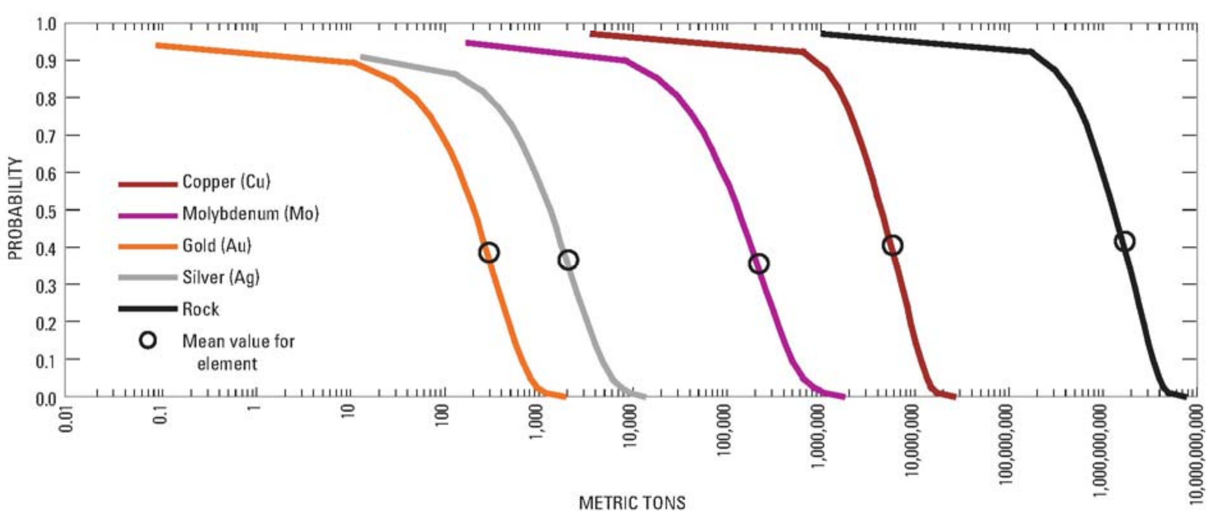

Figure 4. Cumulative distribution of contained metal and mineralized rock in porphyry copper deposits in tract BCAK.

Tract Names: CUSK1 / CUSK2

Model Name: Copper-(Gold) Skarn
USGS Deposit Model: 18b
Area:
CUSK 1: 11,020 km^2
Mean undiscovered deposits: 4.1
CUSK 2: 1,950 km^2
Mean undiscovered deposits: n.a.

Rationale for Model Choice and Tract Delineation

Carbonate rocks and carbonate rock-bearing lithostratigraphic units that have been intruded by Jurassic, Cretaceous, and/or Tertiary plutons, may host copper-(gold) skarn deposits that fit the model of Cox and Theodore (1986) and Theodore and others (1991).

Tract CUSK 1 (fig. 5) is defined on the presence of Triassic limestone of the Kamishak Formation (Detterman and Reed, 1980; Decker and others, 1994), which crop out in areas intruded by Jurassic, Cretaceous, and Tertiary plutons of the Alaska-Aleutian Range batholith. Where aeroradiometric data are available, tract CUSK1 is characterized by high K/Th ratios, which indicate the presence of felsic rocks, including granitic plutons associated with development of skarn mineralization. This tract also contains carbonate-rock bearing roof pendants of unknown, but probable Triassic age, intruded by stocks in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980). Numerous small copper skarn occurrences are reported in carbonate rocks in roof pendants in the northern Aleutian Range; another occurs in Kamishak Formation limestone west of the range (Newberry and others, 1997; Bickerstaff, 1998; Hawley, 2004). The Kasna Creek deposit is a chalcopyrite- and hematite-bearing skarn that contains an estimated 9 million metric tons grading 1 percent copper. The deposit occurs in Upper Triassic dolomite and limestone near the contact of a Jurassic tonalite (Bickerstaff, 1998).

Tract CUSK 2 (fig. 3) is defined by areas that include blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978), which are part of the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). Late Cretaceous and early Tertiary granitic plutons occur within the Nukluk subterrane in this area, but none are known to intrude limestone. Permissive tract CUSK2 includes no known prospects or occurrences of copper skarn type, and was not further assessed.

Quantitative Estimates

The grade and tonnage model of Jones and Menzie (1986) was selected for the quantitative estimates for tract CUSK1 because of the presence of known copper skarn occurrences within the tract. Additional copper skarn deposits beyond those currently known that have grades and tonnages consistent with the published model are likely in this tract. The number of additional deposits was limited by the small volume of carbonate rocks occurring within the tract. The number of undiscovered copper skarn deposits, consistent with the tonnage and grade curves of Jones and Menzie (1986) (median 0.56 million metric tons, 1.7 weight percent copper), was estimated to be 1 at the 90^{th} percentile, 2 at the 50^{th} percentile and 10 at the 10^{th} percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered copper skarn deposits in tract CUSK1 to be 4.1 (table 3). Table 3 also indicates the possible amount of contained metals within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 6. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 7.

Tract CUSK1 has a 95-percent probability of containing no mineralized rock or metals in median-sized deposits, a 90-percent probability of containing at least 46,000 metric tons of mineralized rock, and a 5-percent probability of containing as much as 880,000 metric tons copper, 22 metric tons gold or 210 metric tons silver (table 3; figs. 6 and 7).

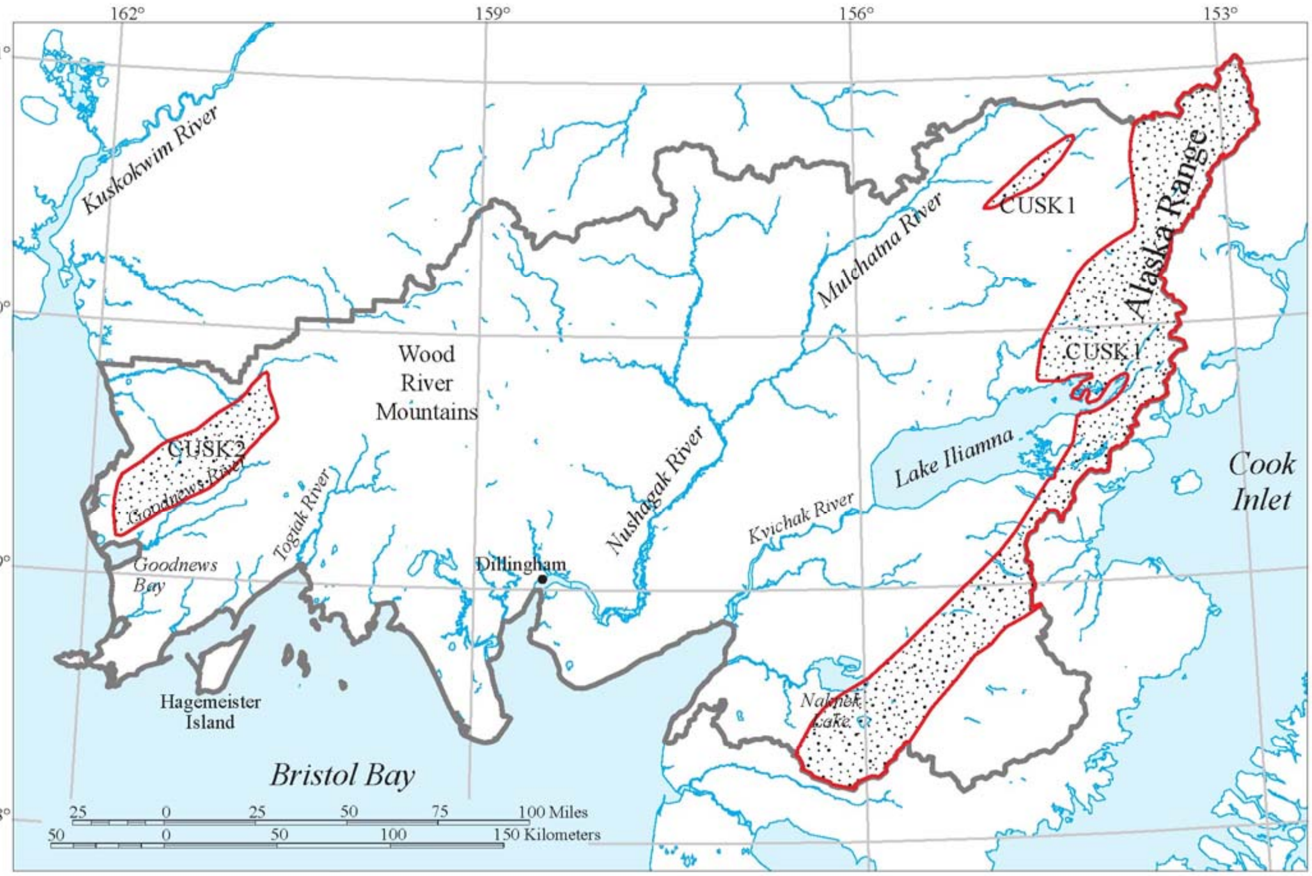

Figure 5. Location of tracts CUSK1 and CUSK2, delineating areas within the Bay RMP area that are permissive for copper skarn deposits, Bay Resource Management Plan area, Alaska.

Table 3. Estimated amounts of contained metal and mineralized rock (metric tons) in copper skarn deposits in tract CUSK1.

[EMINERS index: 7 (Cu Skarn 18b). Mean number of deposits = 4.1.
Abbreviations: Cu, copper; Au, gold; Ag, silver]

Quantile	Cu	Au	Ag	Rock
0.95	0	0	0	0
0.90	1,200	0	0	46,000
0.50	84,000	0.3	4	6,000,000
0.10	620,000	12	167	56,000,000
0.05	880,000	22	210	87,000,000
Mean	220,000	4	46	18,000,000
Probability of mean	0.31	0.22	0.26	0.28
Probability of zero	0.07	0.44	0.46	0.07

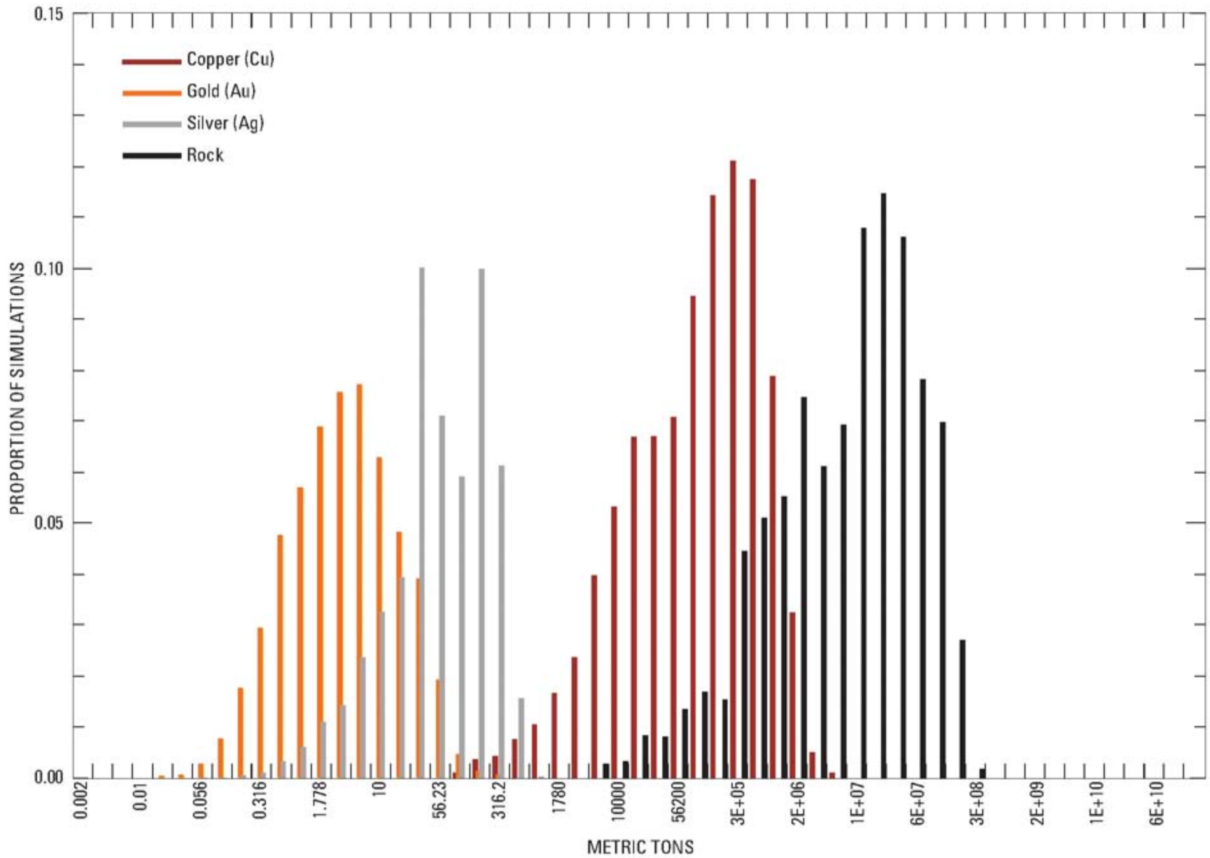

Figure 6. Contained metal and mineralized rock in copper skarn deposits in tract CUSK1.

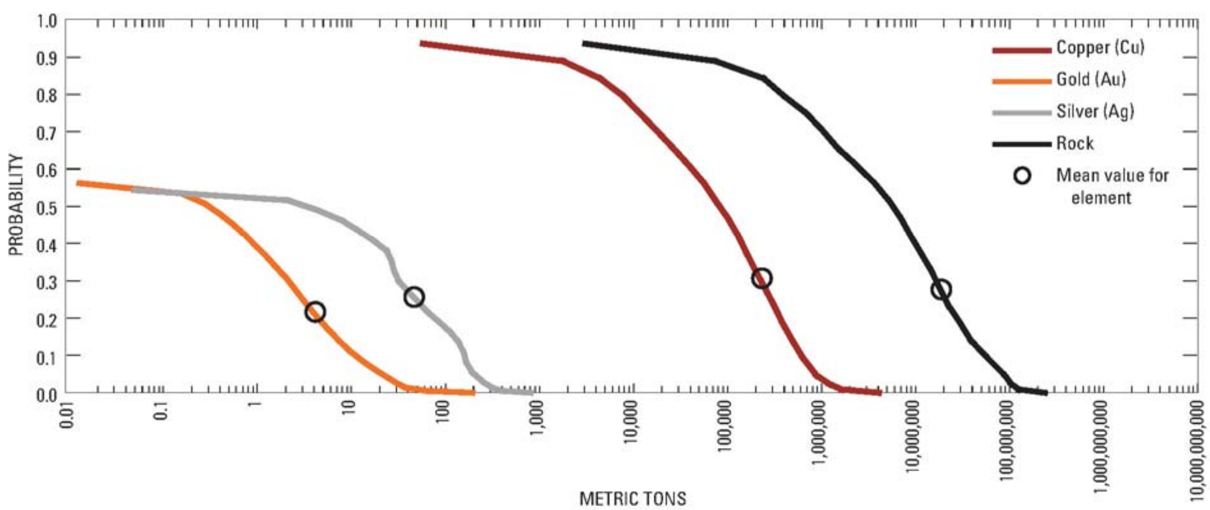

Figure 7. Cumulative distribution of contained metal and mineralized rock in copper skarn deposits in tract CUSK1.

Tract Name: EPIV

Model Name: Epithermal Veins
USGS Deposit Model: 25d
Area: 43,470 km^2
Mean undiscovered deposits: 9.5

Rationale for Model Choice and Tract Delineation

Epithermal precious metal vein deposit models worldwide have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). Information about Alaska (Gray and others, 1997) is inadequate to classify individual epithermal gold vein occurrences or districts. Therefore, we have used a generic epithermal vein model for delineation of the permissive tracts, implying no direct comparison to hot spring- (Berger, 1986a), Creede- (Mosier, Sato and others, 1986), Comstock- (Mosier, Singer and Berger, 1986), or Sado- (Mosier, Berger and Singer, 1986) type descriptive models.

Tract EPIV (fig. 8) primarily was defined on the presence of Tertiary volcanic and shallow intrusive rocks (Detterman and Reed, 1980; Nelson and others, 1983; Riehle and others, 1993; Wilson and others, 2003) that are permissive hosts for epithermal vein deposits. The tract includes isolated gold and silver stream-sediment geochemical anomalies and its western boundary was delineated by regional aeromagnetic data to encompass a large magnetic domain in the southeastern part of the BMPA. This domain is characterized by abundant short wavelength, high amplitude magnetic anomalies, most likely caused by magnetite-bearing intrusive rocks at relatively shallow depths in the subsurface. Tract EPIV also is characterized by high K/Th ratios where aeroradiometric data are available. The high K/Th values indicate the presence of felsic rocks, including subvolcanic and extrusive rhyolites, which may be hosts or causative intrusions for epithermal precious metal vein deposits. Tract EPIV in large part overlies tract BCAK (permissive for porphyry copper deposits), because epithermal vein deposits form at shallower levels in the crust but in the same tectonic environments as porphyry deposits.

Placer gold occurrences in drainages west and north of Sugarloaf Mountain (Church and others, 1992) and vein occurrences such as the Sill prospect (Schrader, 2001; Hawley, 2004) suggest that this tract, like the portion of the Alaska Peninsula underlain by Tertiary volcanic rocks, is permissive for the occurrence of high-grade epithermal gold veins.

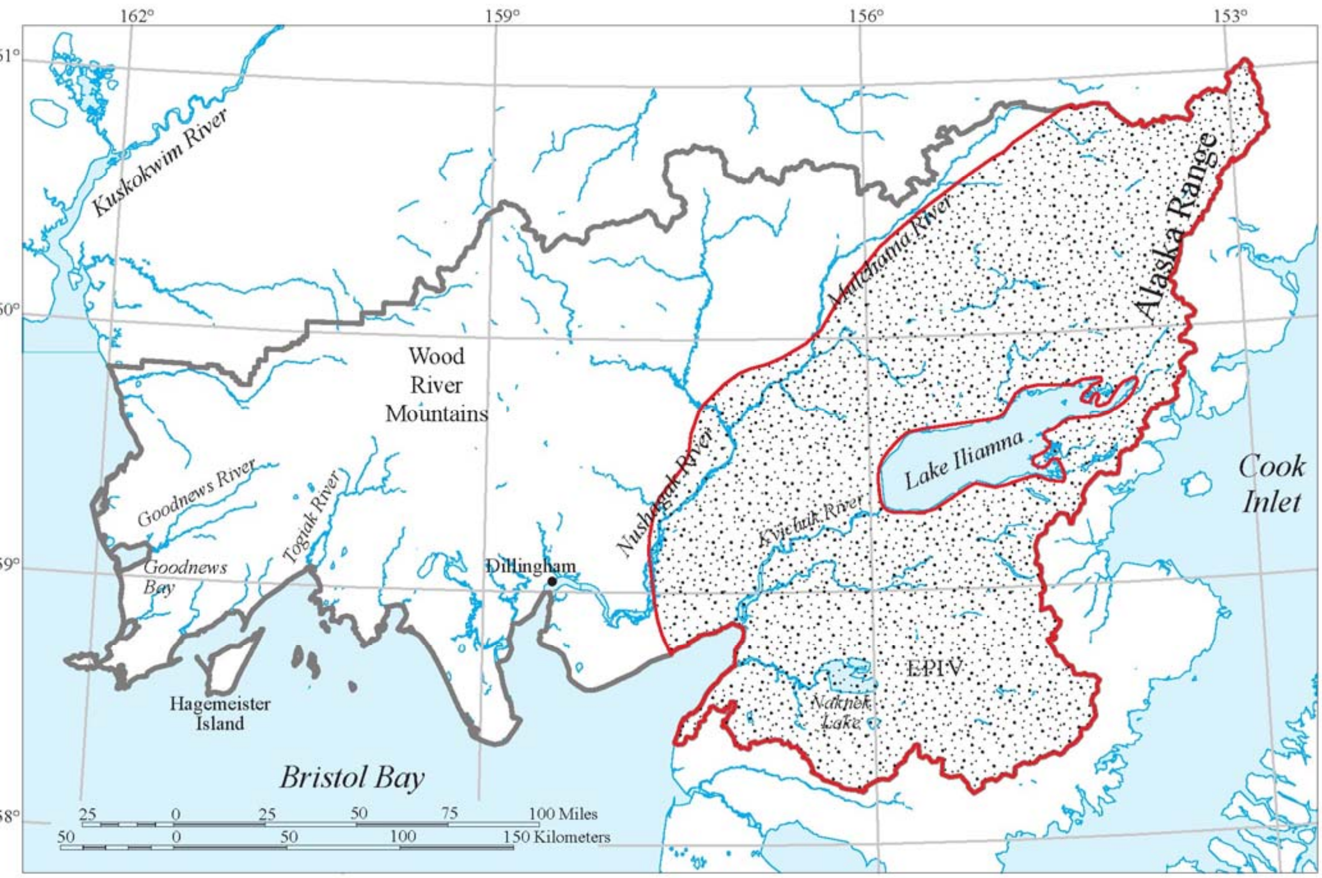

Figure 8. Location of tract EPIV, delineating areas within the Bay RMP area that are permissive for epithermal vein deposits.

Quantitative Estimates

The grade and tonnage model for Sado-type epithermal vein deposits (model 25d; Mosier and Sato, 1986) was selected for use in making the quantitative estimates for tract EPIV, rather than those for Creede-type or Comstock-type veins. Tract EPIV overlies a basement dominated by igneous (volcanic and intrusive) rocks, rather than clastic or sedimentary rocks, suggesting that the Sado model is the most geologically appropriate. The level of uncertainty is still high with respect to the geologic variables that most closely control the style of epithermal mineralization in this region. Additional epithermal vein deposits beyond those currently known, that have grades and tonnages within the range of the Sado model, are likely within this tract. The number of additional deposits likely was estimated based on the geologic assumption that all felsic volcanic rocks in the area are equally likely to be causative or host rocks.

The number of undiscovered deposits, consistent with the grade and tonnage curves of Mosier and Sato (1986) (median 0.3 million metric tons, 6 gpt gold, 38 gpt silver), was estimated to be 3 at the 90th percentile, 7 at the 50th percentile and 20 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered epithermal vein deposits within tract EPIV to be 9.5 (table 4). Table 4 also indicates the possible amount of contained metals within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 9. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 10.

Tract EPIV has a 95-percent probability of containing at least 240,000 metric tons of mineralized rock, and a 5-percent probability of containing as much as 42,000 metric tons copper; 320 metric tons gold; 2,100 metric tons zinc; 6,400 metric tons silver; or 200 metric tons lead (table 4; figs. 9 and 10).

Table 4. Estimated amounts of contained metal and mineralized rock (metric tons) in epithermal vein deposits in tract EPIV.

[EMINERS index: 24 (Sado Epithermal Vein 25d). Mean number of deposits = 9.5. **Abbreviations:** Cu, copper; Au, gold; Ag, silver; Zn, zinc; Pb, lead]

Quantile	Cu	Au	Zn	Ag	Pb	Rock
0.95	0	1	0	9	0	240,000
0.90	15	5	0	41	0	940,000
0.50	12,000	69	0	1,300	2	11,000,000
0.10	36,000	250	1,600	5,000	150	37,000,000
0.05	42,000	320	2,100	6,400	200	46,000,000
Mean	15,000	100	470	2,000	45	16,000,000
Probability of mean	0.41	0.39	0.34	0.38	0.34	0.41
Probability of zero	0.10	0.03	0.64	0.03	0.44	0.03

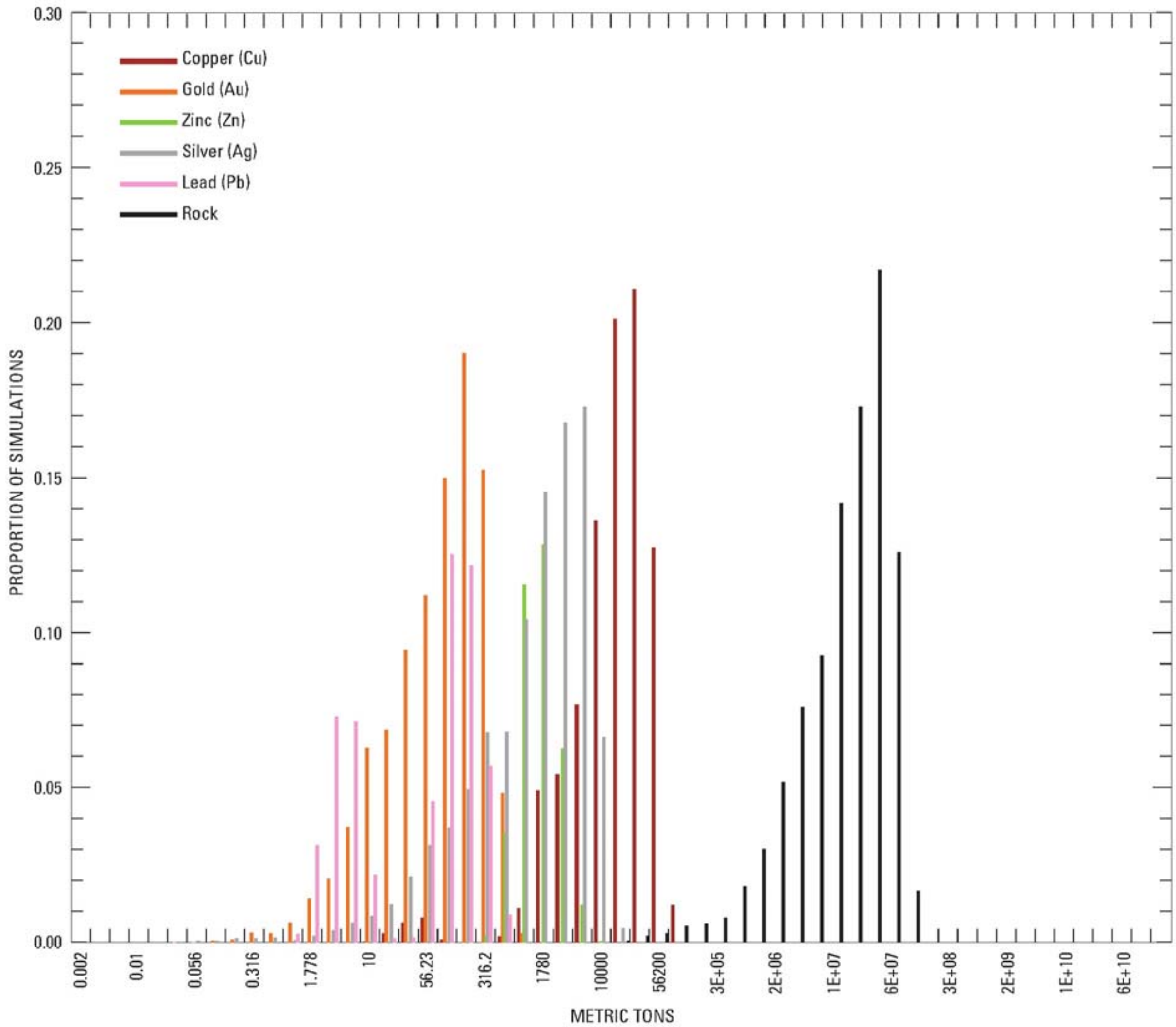

Figure 9. Contained metal and mineralized rock in epithermal vein deposits in tract EPIV.

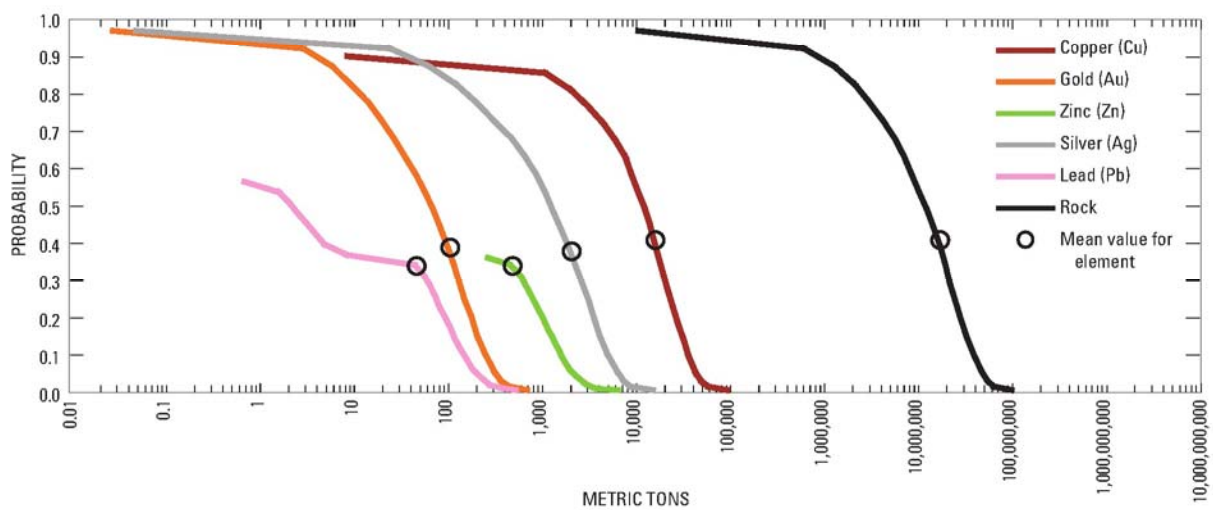

Figure 10. Cumulative distribution of contained metal and mineralized rock in epithermal vein deposits in tract EPIV.

Tract Names: FESK1 / FESK2

Model Name: Iron Skarn
USGS Deposit Model: 18d
Area:
FESK 1: 11,020 km^2
Mean undiscovered deposits: 4.1
FESK 2: 1,950 km^2
Mean undiscovered deposits: n/a

Rationale for Model Choice and Tract Delineation

Carbonate rocks and carbonate rock-bearing lithostratigraphic units that have been intruded by Jurassic, Cretaceous, and/or Tertiary plutons, may host Fe skarn deposits that fit the model of Cox (1986b). Tract FESK1 (fig. 11) is identical to tract CUSK1 (fig. 5) as it also is defined on the presence of Triassic limestones of the Kamishak Formation (Decker and others, 1994; Detterman and Reed, 1980), which crop out in areas intruded by Jurassic, Cretaceous, and Tertiary plutons of the Alaska-Aleutian Range batholith. Where aeroradiometric data are available, tract FESK1 is characterized by high K/Th ratios, which indicate the presence of felsic rocks, including granitic plutons associated with development of skarn mineralization. Tract FESK1 also contains carbonate-rock bearing roof pendants of unknown, but probable Triassic, age, intruded by stocks in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980). Small (<1 million metric tons) skarn occurrences of the calcic Fe (copper-gold) type are reported in carbonate rocks in roof pendants in the northern Aleutian Range; another skarn occurs in Kamishak Formation limestone west of the range (Newberry and others, 1997; Bickerstaff, 1998; Hawley, 2004). The Kasna Creek skarn includes hematite but generally is classified as a copper skarn; it occurs in Upper Triassic dolomite and limestone near the contact of a Jurassic tonalite (Bickerstaff, 1998).

Tract FESK2 is defined by areas that include blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978) that are part of the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). Late Cretaceous and early Tertiary granitic plutons occur within the Nukluk subterrane in this area, but none are known to intrude limestone. Permissive tract FESK2 includes no known prospects or occurrences of iron skarn type, and was not further assessed.

Quantitative Estimates

The grade and tonnage model of Mosier and Menzie (1986) was selected for the quantitative estimates for tract FESK1 because of the presence of known prospects of iron skarn in the tract. Additional iron skarn deposits, beyond those currently known, that have grades and tonnages similar to the published model, are likely within this tract. The number of undiscovered Fe skarn deposits, consistent with the tonnage and grade curves of Mosier and Menzie (1986) (median 7.2 million metric tons, 50.0 weight percent Fe), was estimated to be 1 at the 90th percentile, 2 at the 50th percentile and 10 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered iron skarn deposits in tract FESK1 to be 4.1 (table 5). Table 5 also indicates the possible amount of contained metal within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 12. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 13.

Tract FESK1 has a 95-percent probability of containing no mineralized rocks or iron in median-sized deposits, a 90-percent probability of containing at least 590,000 metric tons of mineralized rock, and a 5-percent probability of containing as much as 970 million metric tons of iron (table 5; figs. 12 and 13).

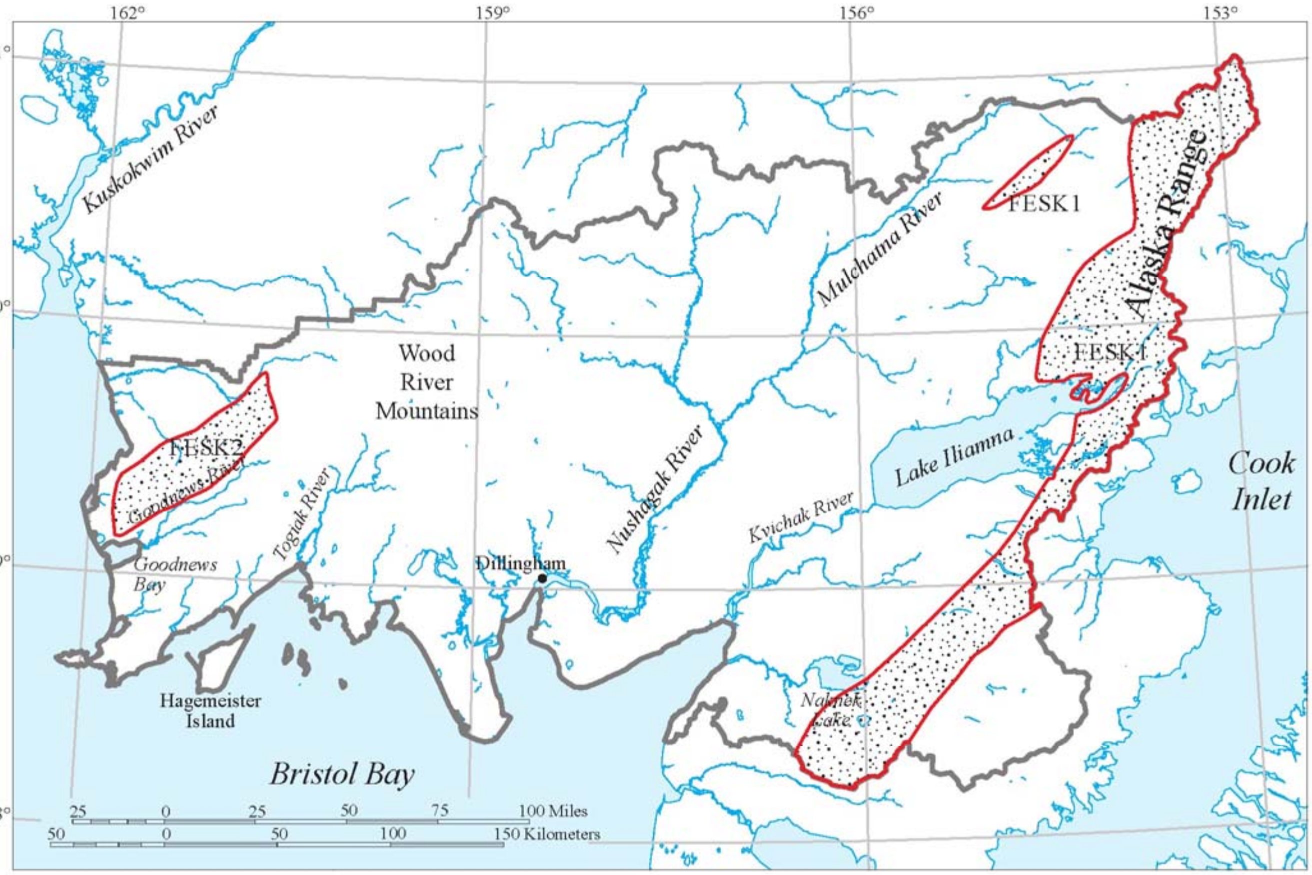

Figure 11. Location of tracts FESK1 and FESK2, delineating areas within the Bay RMP area that are permissive for iron skarn deposits.

Table 5. Estimated amounts of contained metal and mineralized rock (metric tons) in iron skarn deposits in tract FESK1.

[EMINERS index: 6 (Fe Skarn 18d). Mean number of deposits = 4.1. **Abbreviation:** Fe, iron]

Quantile	Fe	Rock
0.95	0	0
0.90	330,000	590,000
0.50	35,000,000	78,000,000
0.10	560,000,000	1,700,000,000
0.05	970,000,000	2,700,000,000
Mean	170,000,000	480,000,000
Probability of mean	0.25	0.23
Probability of zero	0.06	0.06

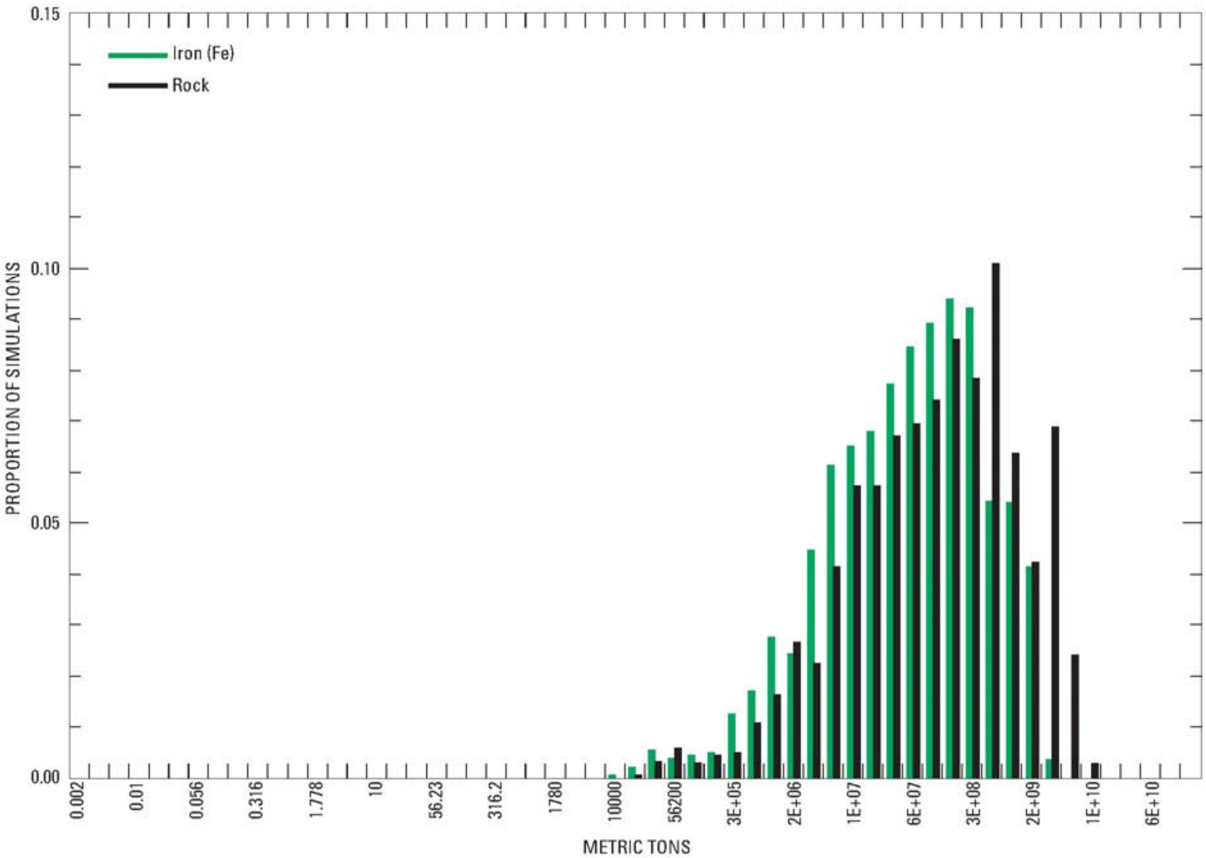

Figure 12. Contained metal and mineralized rock in iron skarn deposits in tract FESK1.

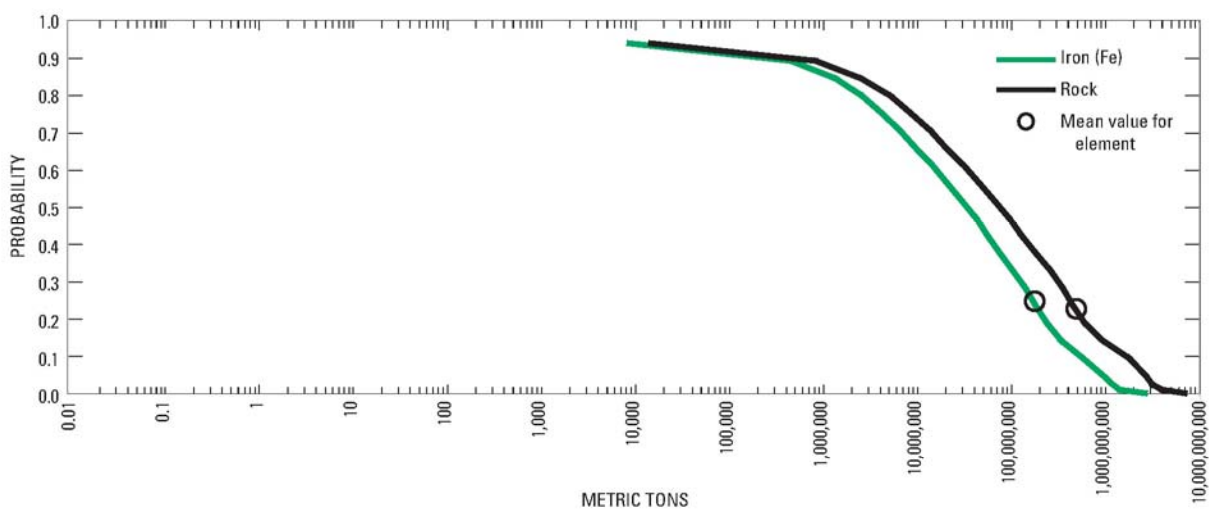

Figure 13. Cumulative distribution of contained metal and mineralized rock in iron skarn deposits in tract FESK1.

Tract Name: HG

Model Name: Hot-Spring Hg
USGS Deposit Model: 27a, b, c
Area: 47,570 km^2
Mean undiscovered deposits: 2.5

Rationale for Model Choice and Tract Delineation

Mercury deposit models worldwide have been divided into several types based largely on their mineralogy and host rocks. Descriptive models include those for Almaden (Rytuba, 1986a), hot-spring (Rytuba, 1986b), and silica-carbonate (Rytuba, 1986c) type deposits, and a related precious-metal hot-spring model (Berger, 1986a). Information about the mercury deposits in Alaska) is limited (Gray and others, 1997) but suggests that they are vein and subvolcanic occurrences, locally containing anomalous gold. Some occur alone, some are associated with gold deposits of various types, but they are not typical of any one of the published descriptive models.

The Brewery Creek (Diment and Simpson, 2003) and Donlin Creek (Goldfarb and others, 2004) intrusion-related gold (IRG) deposits contain elevated contents of mercury, and some models of IRG systems suggest that mercury (along with arsenic and antimony) is characteristic of deposits which are more peripheral to intrusions (Lang and others, 2000) or which formed at the shallowest levels in the crust (Baker, 2003). Rytuba and Herapoulos (1992) suggested a direct link between mercury and some types of epithermal gold deposits. Because of the limited knowledge of the southwestern Alaska mercury deposits and the uncertainty in classification schemes and models, we have used a generic mercury deposit model for delineation of the permissive tracts in the BMP area, implying no direct comparison to any of the descriptive models published in Cox and Singer (1986).

Tract HG (fig. 14) was defined by areas that contain sedimentary and lesser volcaniclastic and volcanic rocks of Mesozoic age that are intruded by Late Cretaceous to Tertiary igneous rocks exposed at relatively high (subvolcanic) levels. The potential Mesozoic host rocks include arc assemblages of the Togiak terrane (Decker and others, 1994) and flysch of the Kuskokwim Group (Cady and others, 1955). These are locally intruded by dikes of felsic, intermediate or, less commonly, mafic composition. Where aeroradiometric data are available, tract HG is characterized by low K/Th values, indicating a lack of extensive granitic and felsic rocks exposed at the surface.

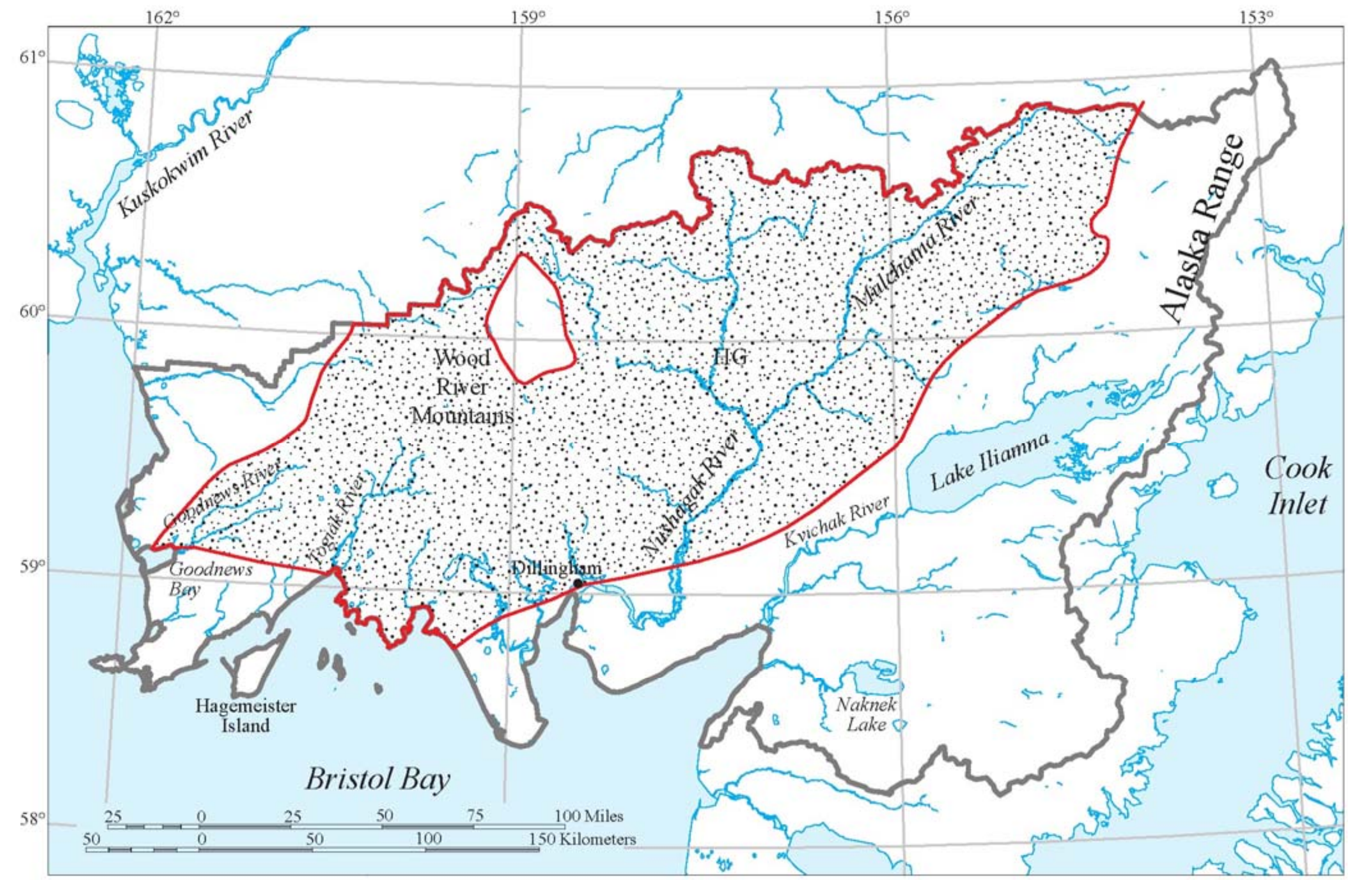

Figure 14. Location of tract HG, delineating areas within the Bay RMP area that are permissive for hot spring mercury deposits.

Mercury-antimony prospects and mines, some containing elevated gold, are common in the Kuskokwim Mountains just north of the BMPA. The Red Top mine (Sainsbury and MacKevett, 1965; Hudson, 2001a) in tract HG produced more than 60 flasks of mercury from cinnabar-quartz-carbonate veins in brecciated siltstone and graywacke cross cut by altered felsic dikes.

Quantitative Estimates

Two grade and tonnage models have been developed for mercury deposits (Rytuba, 1986d, 1986e). The hot-spring mercury model (model 27a; Rytuba, 1986d) was chosen for the quantitative estimates for tract HG, because this model includes a geographically dispersed group of deposits and a wider variety of host rocks than the silica-carbonate mercury model (model 27c; Rytuba, 1986e). This model is therefore more representative of conditions within tract HG.

Additional mercury ± antimony ± gold deposits, beyond those currently known, that have grades and tonnages similar to the hot-spring mercury model are likely within this tract. The number of undiscovered mercury deposits, consistent with the tonnage and grade curves of Rytuba (1986d) (median 0.0095 million metric tons, 0.35 weight percent mercury), was estimated to be 1 at the 90th percentile, 2 at the 50th percentile and 5 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered hot-spring mercury deposits in tract HG to be 2.5 (table 6). Table 6 also indicates the possible amount of contained metal within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 15. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 16.

Tract HG has a 95-percent probability of containing no mineralized rock or mercury in median-size deposits, a 90-percent probability of containing at least 180 metric tons of mineralized rock, and a 5-percent probability of containing as much as 12,000 metric tons of mercury (table 6; figs. 15 and 16).

Table 6. Estimated amounts of contained metal and mineralized rock (metric tons) in hot spring Hg deposits in Tract HG.

[EMINERS index: 25 (Hot Springs Hg 27a). Mean number of deposits = 2.5. **Abbreviation:** Hg, mercury]

Quantile	Hg	Rock
0.95	0	0
0.90	1	180
0.50	400	120,000
0.10	8,100	2,300,000
0.05	12,000	3,100,000
Mean	2,200	580,000
Probability of mean	0.23	0.24
Probability of zero	0.07	0.07

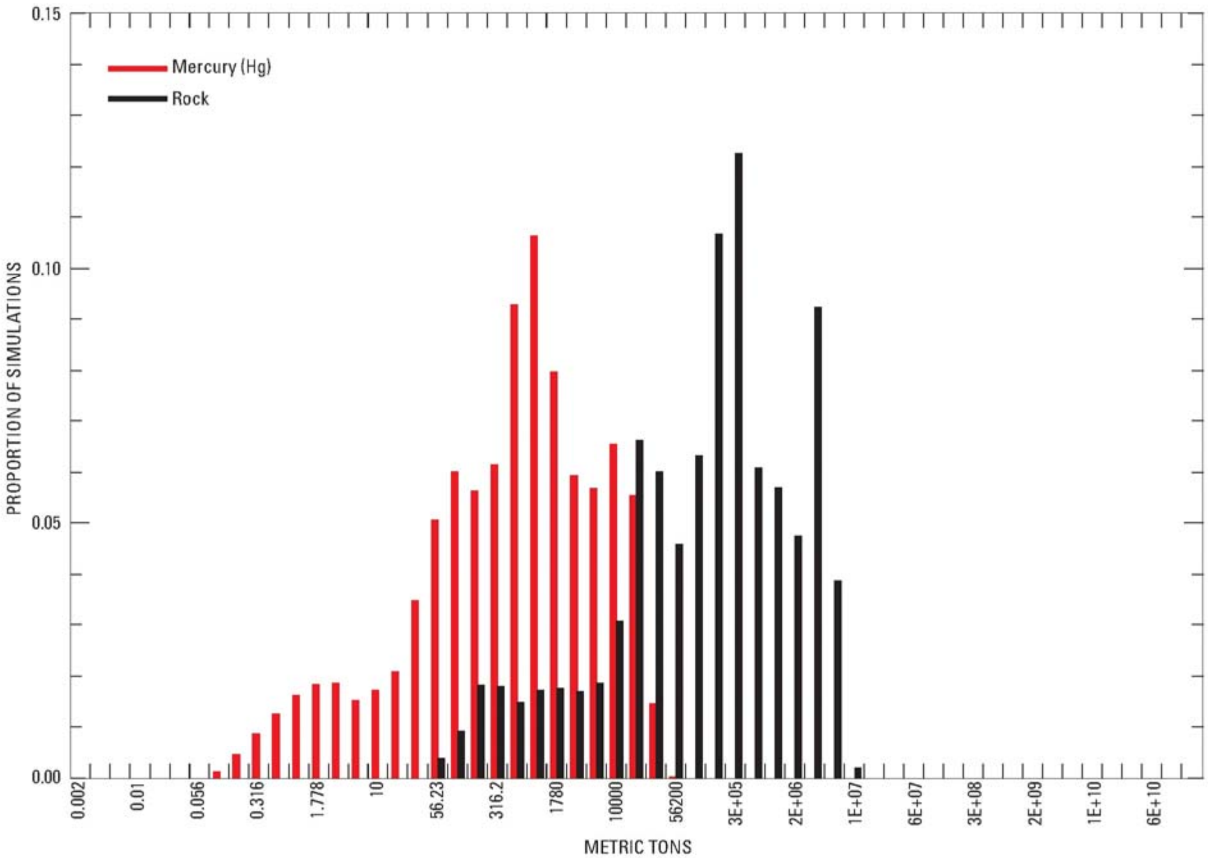

Figure 15. Contained metal and mineralized rock in hot-spring mercury deposits in tract HG.

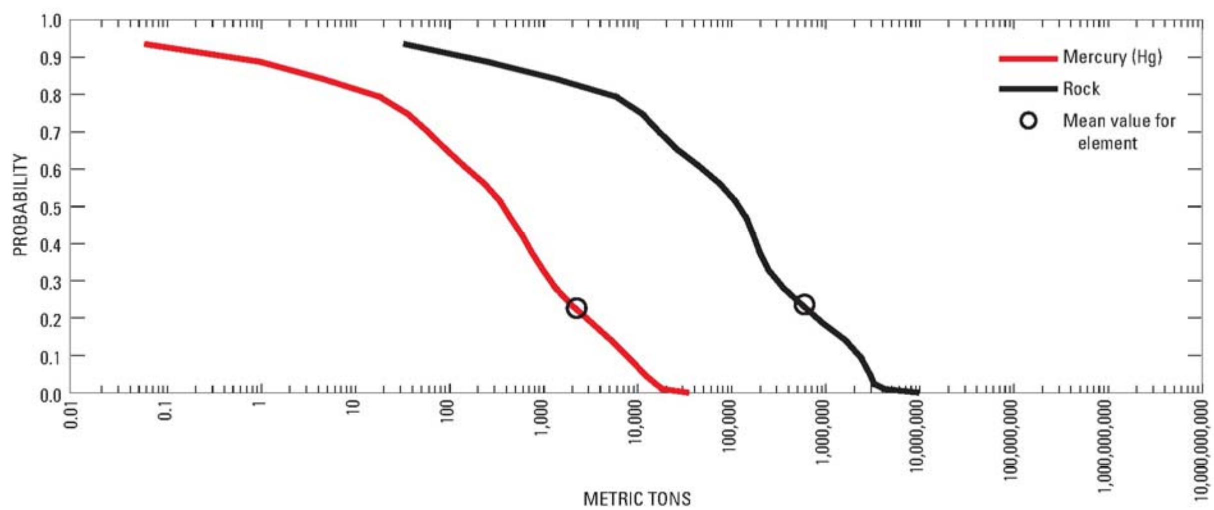

Figure 16. Cumulative distribution of contained metal and mineralized rock in hot-spring mercury deposits in tract HG.

Tract Name: IRG-SIL

Model Name: Intrusion-Related Gold (Shallow-Intermediate Level)
USGS Deposit Model: n/a
Area: 42,260 km^2. Mean undiscovered deposits: 1.9

Rationale for Model Choice and Tract Delineation

Available published USGS models are not appropriate to describe the gold deposits of southwestern Alaska or to assess gold deposits in the BMP area. Therefore, we have adapted recently published descriptive models from industry and developed a new, but incomplete grade and tonnage model for this assessment. This model, which we term "intrusion-related gold, shallow- to intermediate-level" (IRG-SIL), more accurately reflects the deposits known in the region and the geologic conditions of the region. Our model comprises only deposits emplaced at intermediate to shallow levels (0–5 km) in the crust that are part of a larger gold-mineralizing system related to intermediate- to felsic-composition intrusions. The full suite of deposits generally are referred to as "intrusion-related gold" (IRG) systems (Flanigan and others, 2000; Lang and others, 2000; Baker, 2002, 2003; Hart, 2005; Lefebure and Hart, 2005) and include a variety of deposit styles including sheeted and single veins, stockworks, disseminations, breccias, replacement, and skarn deposits. IRG deposits are characterized by low sulfide contents, a predominance or arsenopyrite over pyrite, a gold-bismuth-tellurium±tungsten association at deeper levels, and elevated antimony-arsenic-mercury ± tin (Baker, 2003) at shallower levels. The "plutonic porphyry gold" model of Hollister (1992) as well as the Fort Knox, Pogo, and Dublin Gulch deposits (Flanigan and others, 2000; Baker, 2003) represent the deeper levels of the IRG system. Previous assessments (U.S. Geological Survey, 2000) referred to some of the shallower deposits, which we include here in the IRG-SIL model as "peraluminous granite porphyry gold" (Bundtzen and Miller, 1997).

Tract IRG-SIL (fig. 17) was defined on the presence of intrusive rocks and favorable gold geochemical data (Bundtzen and Miller, 1997; and U.S. Geological Survey, 2004). The tract was drawn to include all known or inferred Upper Cretaceous to Lower Tertiary (ca. 100–50 Ma) felsic stocks and rhyolite and aphanitic to porphyritic granite dikes that intrude turbidites of the Upper Cretaceous Kuskokwim Group).

Tract IRG-SIL contains the Shotgun gold prospect (Hudson, 2001e; Rombach and Newberry, 2001). The Donlin Creek (Goldfarb and others, 2004; Ebert and others, in press), Vinasale (DiMarchi, 1993), and Chicken Mountain (Bundtzen and Miller, 1997) shallow intrusion-related gold deposits are located tens of kilometers north of the boundary of the BMPA.

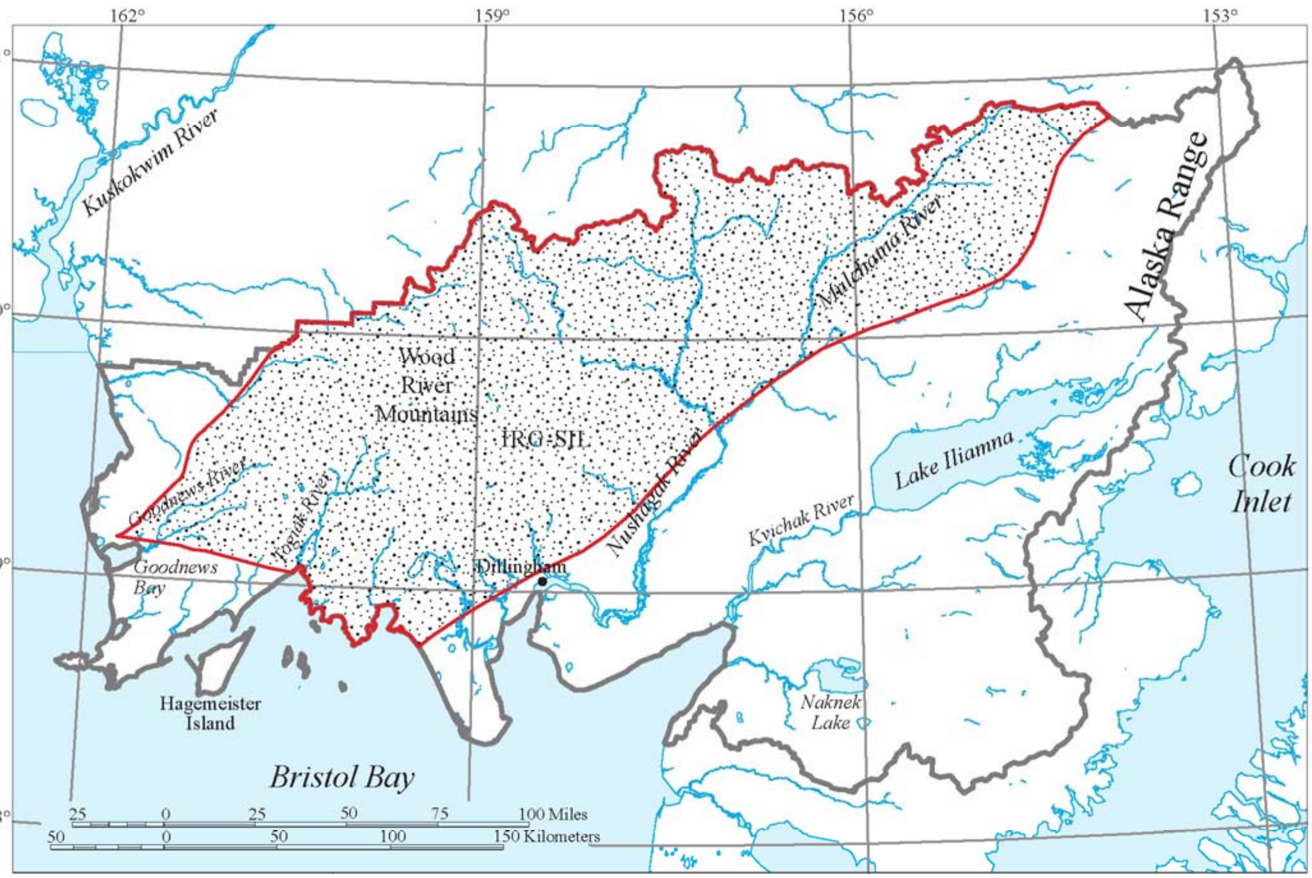

Figure 17. Location of tract IRG-SIL, delineating areas within the Bay RMP area that are permissive for shallow- to intermediate-level intrusion-related gold deposits.

Quantitative Estimates

No grade and tonnage models for either deep or shallow-to-intermediate level intrusion related gold deposits have yet been published. However, recent exploration and mining in Alaska and Yukon have identified a significant number of gold deposits emplaced at shallow-to-intermediate-levels and related to ilmenite-series or reduced granitoid intrusions. Grades and tonnages of gold deposits interpreted as occurring at shallow to intermediate levels in the crust and related to intrusions are listed in table 7. U.S. Geological Survey Circular 831 (U.S. Bureau of Mines and U.S. Geological Survey, 1980; table 8) defines the terms "reserves," "resources," "inferred," "indicated," and "measured" used in table 7. This list of deposits used for the IRG-SIL model specifically exclude Fort Knox, Dublin Gulch, Pogo and other IRG deposits (Hart, 2005) known to have formed at deeper levels (>5 km) in the crust. The grades and tonnages of the deposits listed in table 7 were input into the EMINERS program in order to create a frequency distribution curve for estimation of the possible sizes and grades for undiscovered deposits of like characteristics. This group of 13 deposits, therefore, serves as a preliminary grade and tonnage model for the shallow-to intermediate level intrusion-related gold deposits that are expected to occur in the Bay RMP area.

Table 7. Grade and tonnage data for 13 shallow-to-intermediate level intrusion-related gold deposits worldwide.

[**Abbreviations:** gpt, gram per metric ton; oz, Troy ounce; Au, gold; ppm, parts per million]

Location	Name	Date of data	Category of resource	Tonnage (million tonnes)	Grade (gpt=ppm)	Million oz. Au	Reference	Comments
Yukon	Brewery Creek		production (oxide ore)	17.1	1.44		Diment and Simpson, 2003	
Southwest Alaska	Chicken Mountain		inferred resource?	14.5	1.2		Bundtzen and Miller, 1997	
Interior Alaska	Dolphin		inferred resource?	30	0.68	0.6	Flanigan and others, 2000; Avalon Development Corp., 2005	
Southwest Alaska	Donlin Creek	2005	resources (measured, indicated and inferred)	205.14	3.5	23.09	Ebert and others, in press	"average grade"
Southwest Alaska	Golden Horn	1992	production	2.85	1.2		Bundtzen and others, 1992	
Australia	Kidston	1991	inferred resource?	94	1.48		Baker and Andrew, 1991; Baker, 2002	
Bolivia	Kori Kollo		inferred resource?	64	2.3	4.83	Petersen and Fitzmayer, 1998; Baker, 2002	
Southwest Alaska	Owhat-Mission Creek	1991	inferred resource?	0.229	4.498		Bundtzen and Laird, 1991	
Interior Alaska	Ryan Lode		total reserves	13.24	1.93	0.822	Szumigala and Hughes, 2005	at a 0.5 gpt cutoff
Southwest Alaska	Shotgun	1999	inferred resource	32.765	0.93	0.98	St George and Schneider, 1999; Freeman, C.J., 2002	at a 0.5 gpt cutoff;
Southwest Alaska	Vinasale	2004	inferred resource?	13.01	2.3	0.961	Szumigala and Hughes, 2005	at a 1.03 gpt cutoff
Interior Alaska	True North	2004	mined 2001 through 2004	10	1.37	0.44	Szumigala and Hughes, 2005	
Interior Alaska	Golden Zone	2005	preliminary measured and indicated resources	2.8	2.81	0.253	Hurst, 2005	at a 1 gpt cutoff

Table 8. Elements of a resource classification ("McKelvey diagram").

	Identified resources			Undiscovered resources		
	Demonstrated		Inferred	Probability range		
	Measured	Indicated		90%	50%	10%
Economic	Reserves		Inferred reserves	Resources estimated in this report		
Marginally economic	Marginal reserves		Inferred marginal reserve			
Sub-economic	Demonstrated subeconomic resources		Inferred subeconomic reserves			

The bimodal nature of the distribution of contained gold (fig. 18) is a result of the large gap in size between the Donlin Creek deposit and other examples used here (table 7). Because intrusion-related gold deposits have only recently been recognized as a class, many prospects are under active exploration, but few have reached the development stage at which quantitative reserves and resource information is released. We anticipate that additional discoveries and future announcements from deposits recognized as the intermediate- to shallow levels of the IRG suite will eventually fill this apparent gap in the distribution.

Additional shallow-to-intermediate level intrusion-related gold deposits, beyond those currently known, with grade and tonnage characteristics similar to those listed in table 7 are likely to occur in tract IRG-SIL. The number of undiscovered shallow to intermediate-level intrusion-related gold deposits, consistent with the newly defined tonnage and grade curves (median ~ 15 Mt, ~1 gpt gold) was estimated to be 0 at the 90th percentile, 1 at the 50th percentile and 5 at the 10th percentile probability levels (table 1).

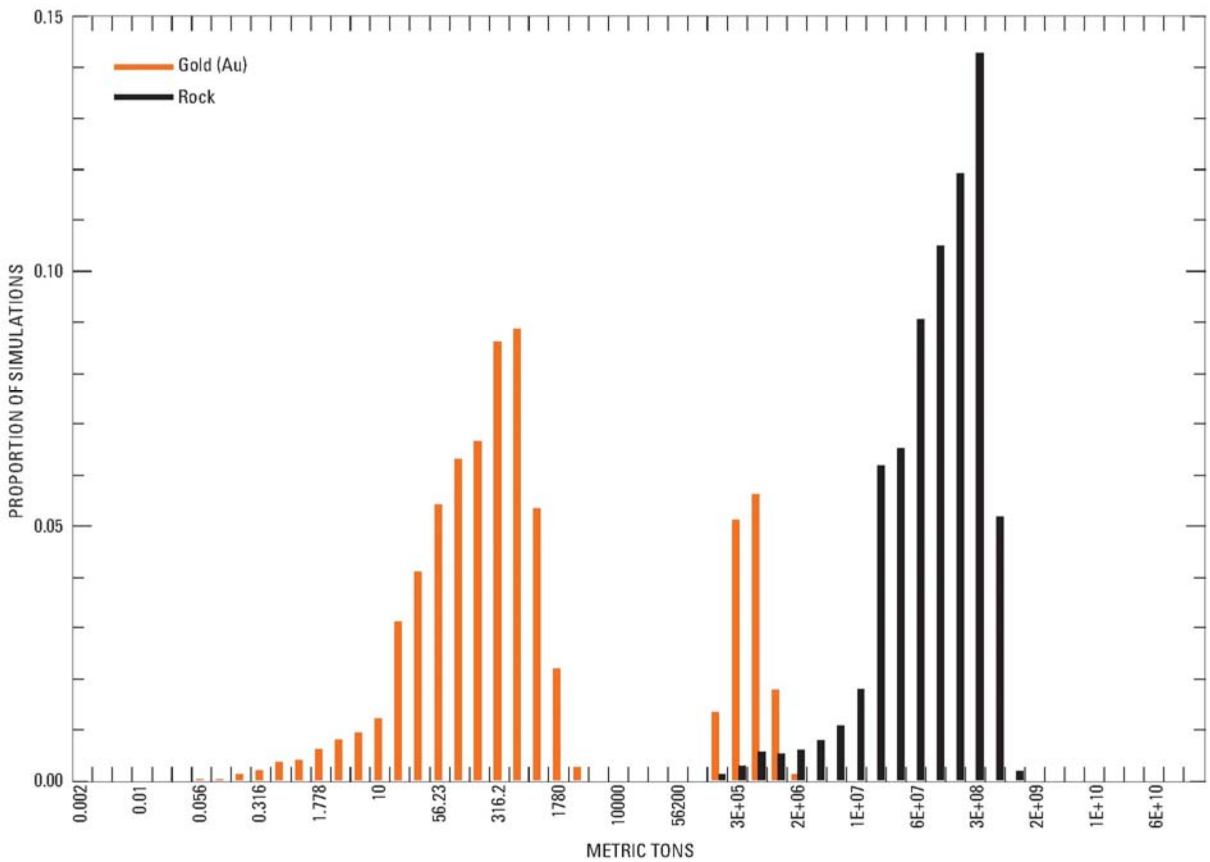

Figure 18. Contained metal and mineralized rock in shallow-to-intermediate level intrusion-related gold deposits in tract IRG-SIL.

From these estimates, the EMINERS program summarizes the mean number of undiscovered shallow- to intermediate-level, intrusion-related gold deposits in tract IRG-SIL to be 1.9 (table 9). Table 9 also indicates the possible amount of contained metal within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 18. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 19.

Tract IRG-SIL has a 95-percent probability of containing no mineralized rock or metals in median-size deposits, a 50-percent probability of containing at least 27 million metric tons of mineralized rock, and a 5-percent probability of containing as much as 750 metric tons of gold (table 9; figs. 18 and 19).

Table 9. Estimated amounts of contained metal and mineralized rock (metric tons) in shallow to intermediate level intrusion-related gold deposits in tract IRG-SIL.

[EMINERS index: (Intrusive Related Gold-Intermediate to Shallow Level). Mean number of deposits = 1.9. **Abbreviation:** Au, gold]

Quantile	Au	Rock
0.95	0	0
0.90	0	0
0.50	49	27,000,000
0.10	530	240,000,000
0.05	750	310,000,000
Mean	170	80,000,000
Probability of mean	0.30	0.33
Probability of zero	0.30	0.30

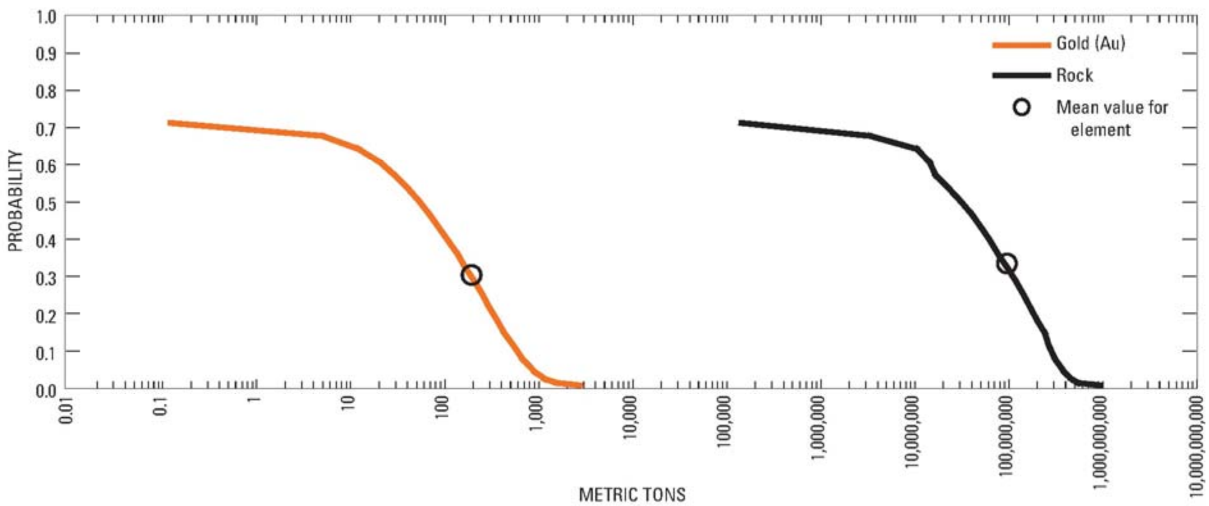

Figure 19. Cumulative distribution of contained metal and mineralized rock in shallow-to-intermediate level intrusion-related gold deposits in tract IRG-SIL.

Tract Name: PGEP

Model Name: Placer PGE (Gold)
USGS Deposit Model: 39b
Area: 11,770 km^2
Mean undiscovered deposits: 9.5

Rationale for Model Choice and Tract Delineation

Platinum-group elements (PGEs), alloys, and associated minor amounts of gold can form placer deposits in unconsolidated and semi-consolidated deposits downstream of any type of PGE-bearing source or lode deposit (Yeend and Page, 1986). Depositional environments for PGE placer accumulations are usually marine shoreline or high-energy alluvial but may include aeolian or *in-situ* deposits.

Tract PGEP (fig. 20) is permissive for placer PGE-gold deposits hosted in Quaternary unconsolidated alluvial and marine sediments. It includes onshore regions and areas up to 10 km offshore that are downstream of known mafic-ultramafic complexes within the Goodnews and Togiak terranes (Hoare and Coonrad, 1978; Decker and others, 1994). These complexes are the primary suspected lode source for the placer PGEs, although no lode deposits have yet been identified. Some of these complexes have been interpreted as ophiolite sequences (Patton and others, 1994). Others, including Red Mountain and Susie Mountain in the Goodnews BMPA (Foley and others, 1997; Hudson, 2001c, 2001d), are Alaskan-type zoned ultramafic complexes similar to those that are the source for abundant placer PGE deposits in the Ural Mountains of Russia.

Placer PGE occurrences are known from within tract PGEP. The record from mining at the Goodnews Bay deposits (Cobb, 1973; Mertie, 1976; Hudson, 2001c, 2001d) suggests that at least 20.2 metric tons of the platinum group elements osmium, iridium, and platinum and 933 kg of gold were produced (Yeend and others, 1987). Grades are uncertain, but concentrates from the mining operation contained a ratio of approximately 1:10 gold: PGEs (Southworth and Foley, 1986).

Quantitative Estimates

A grade and tonnage model for placer PGE-gold deposits has been defined (Singer and Page, 1986); this model is derived entirely from examples in the Ural Mountains of Russia.

Additional placer PGE-gold deposits, beyond those currently known, are likely within tract PGEP. The number of undiscovered deposits, consistent with the grade and tonnage curves of Singer and Page (1986) (median 0.11 million metric tons, 2,500 ppb Pt), was estimated to be 3 at the 90th percentile, 7 at the 50th percentile and 20 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered placer platinum-group element deposits in tract PGEP to be 9.5 (table 10). Table 10 also indicates the possible amount of contained metals within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 21. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 22.

Tract PGEP has a 95-percent probability of containing at least 89,000 metric tons of platinum group element-mineralized sediments of a median size and grade and a 5-percent probability of containing as much as 21 metric tons platinum, or 1 metric ton osmium (table 10; figs. 21 and 22).

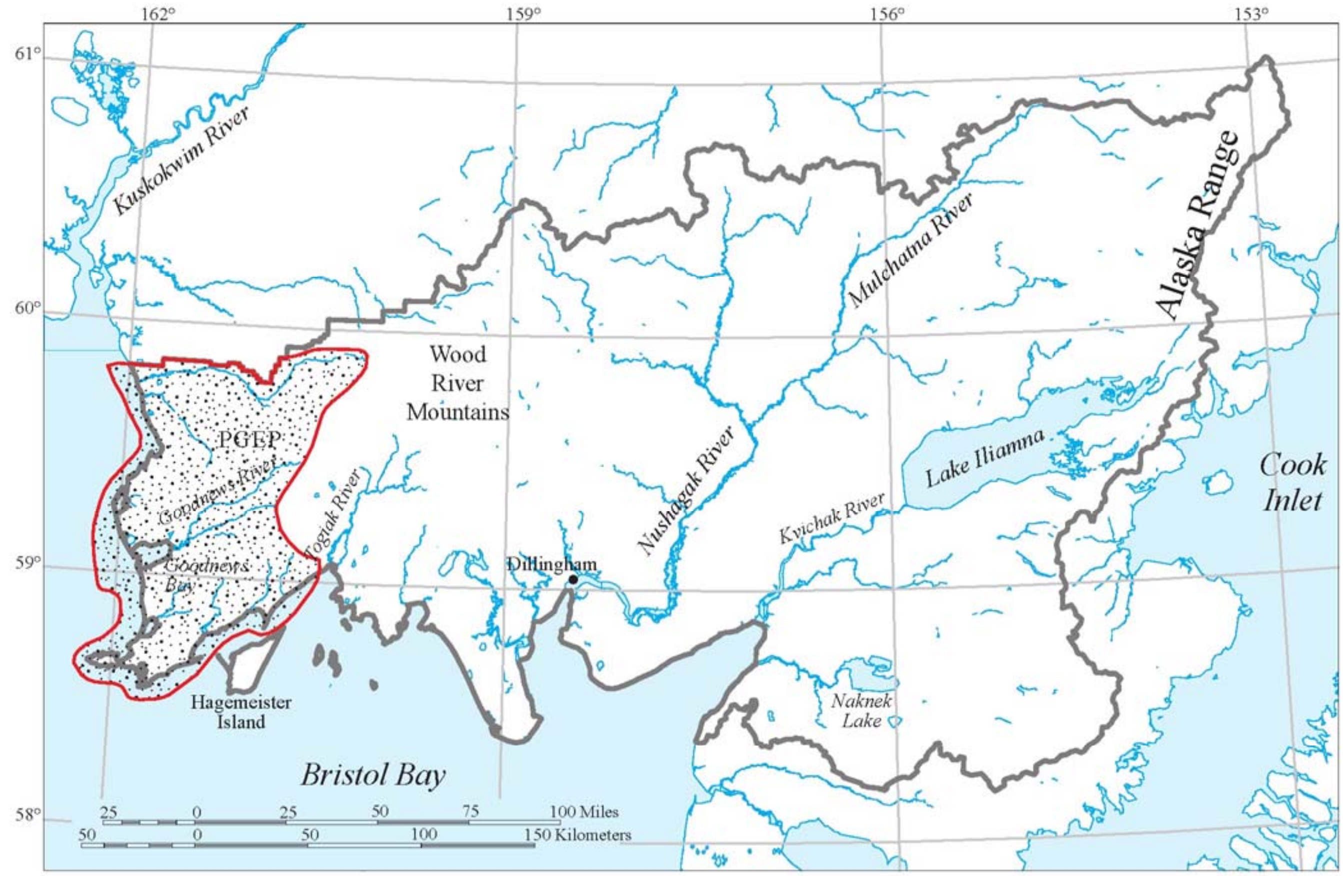

Figure 20. Location of tract PGEP, delineating areas within the Bay RMP area that are permissive for placer platinum-group-element deposits.

Table 10. Estimated amounts of contained metal and mineralized rock (metric tons) in placer platinum-group-element deposits in tract PGEP.

[EMINERS index: 81 (Placer PGE-Au 39b). Mean number of deposits = 9.5. **Abbreviations:** Au, gold; Pt, platinum; Pd, palladium; Ir, iridium; Os, Osmium]

Quantile	Au	Pt	Pd	Ir	Os	Rock
0.95	0	0	0	0	0	89,000
0.90	0	1	0	0	0	390,000
0.50	0.01	5	0	0	0.04	5,000,000
0.10	0.13	17	0.05	0.1	0.3	15,000,000
0.05	0.20	21	0.1	0.2	0.5	18,000,000
Mean	0.04	7	0.02	0.04	0.1	6,500,000
Probability of mean	0.24	0.40	0.24	0.27	0.29	0.41
Probability of zero	0.16	0.03	0.31	0.37	0.18	0.03

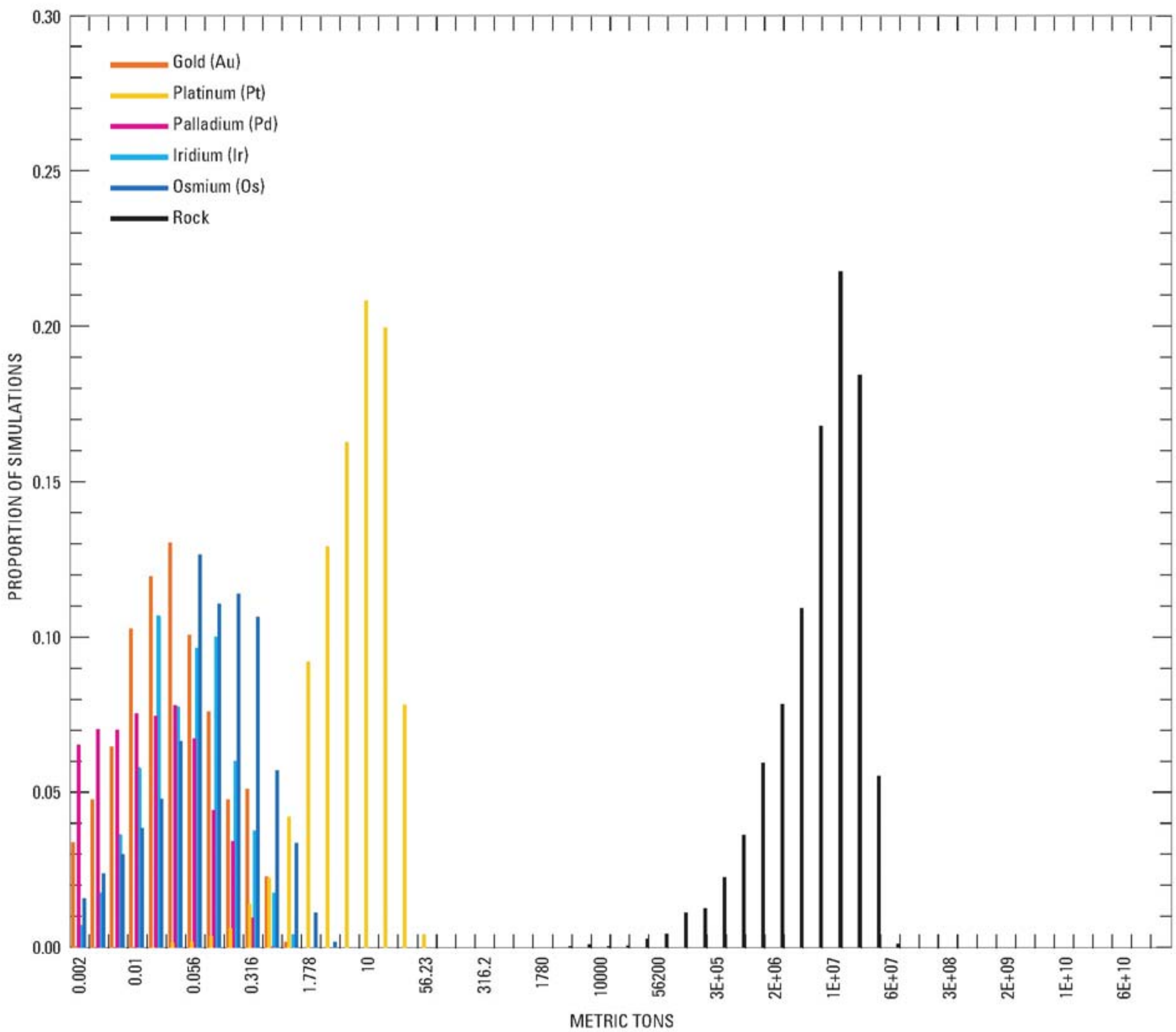

Figure 21. Contained metal and mineralized rock in placer platinum-group element deposits in tract PGEP.

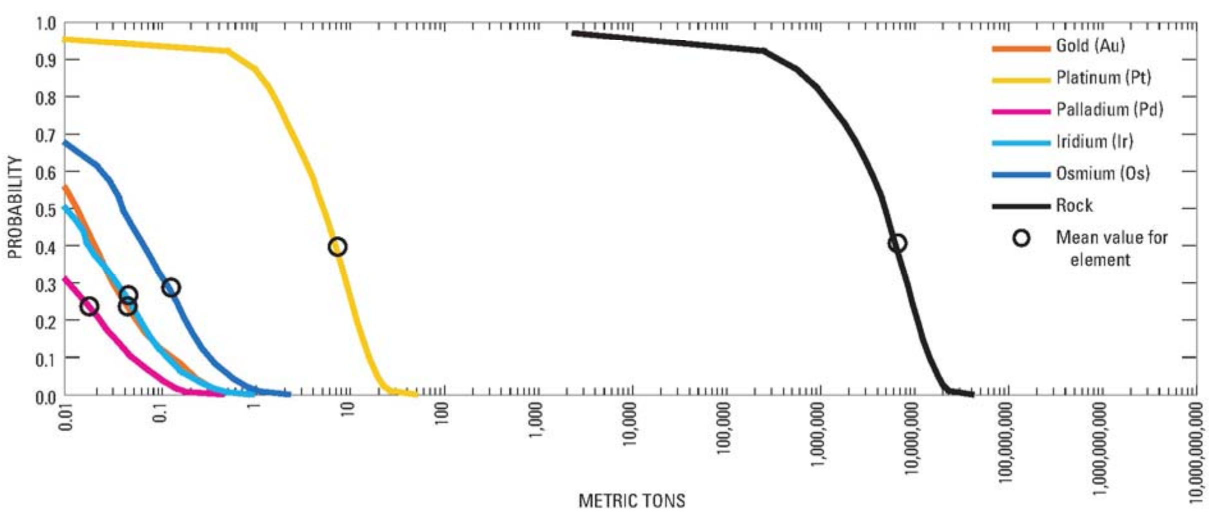

Figure 22. Cumulative distribution of contained metal and mineralized rock in placer platinum-group element deposits in tract PGEP.

Tract Names: PLACER1 / PLACER2

Model Name: Placer Gold (PGE)
USGS Deposit Model: 39a
Area:
PLACER1: 55,350 km²
Mean undiscovered deposits: 3.1
PLACER2: 15,260 km²
Mean undiscovered deposits: n/a

Rationale for Model Choice and Tract Delineation

Placer gold (Yeend, 1986) can occur in unconsolidated and semi-consolidated deposits downstream of gold-bearing lode deposits of any type. Depositional environments for placer accumulations are usually high-energy alluvial, but can be glacial, marine shoreline or aeolian as well. Therefore, the permissive area for placer gold within the BMPA is quite broad. In addition, Quaternary glaciation over parts of the BMPA has significantly redistributed pre-glacial unconsolidated deposits, possibly eroding previously concentrated placers, and /or developing new placer deposits.

Two tracts outline the potential for undiscovered placer gold deposits; together they encompass most of the Bay RMP area (fig. 23).

Tract PLACER1 (fig. 23) comprises a large proportion of the BMPA and includes unconsolidated surficial deposits west of the glaciated Alaska Range, and north of Lake Iliamna. It excludes unconsolidated deposits in very low-lying areas of little relief that are unlikely in the recent geologic past to have developed high-energy depositional environments required for placer formation. The eastern boundary of the tract is defined by the limit of glacial deposits on the west flank of the Alaska and Aleutian Ranges. Tract PLACER1 includes areas in which gold occurs in stream sediment samples, and its southern and western extent was extended into the Dillingham quadrangle to include a known granodiorite body and several geophysical signatures that may indicate unexposed plutons. The Goodnews Bay placer district lies within tract PLACER1 (Cobb, 1973; Yeend and others, 1987). Potential lode sources of gold within the tract include porphyry copper ± gold, intrusion-related gold, epithermal vein, hot-spring mercury, hot-spring gold, and low-sulfide gold-quartz vein deposits.

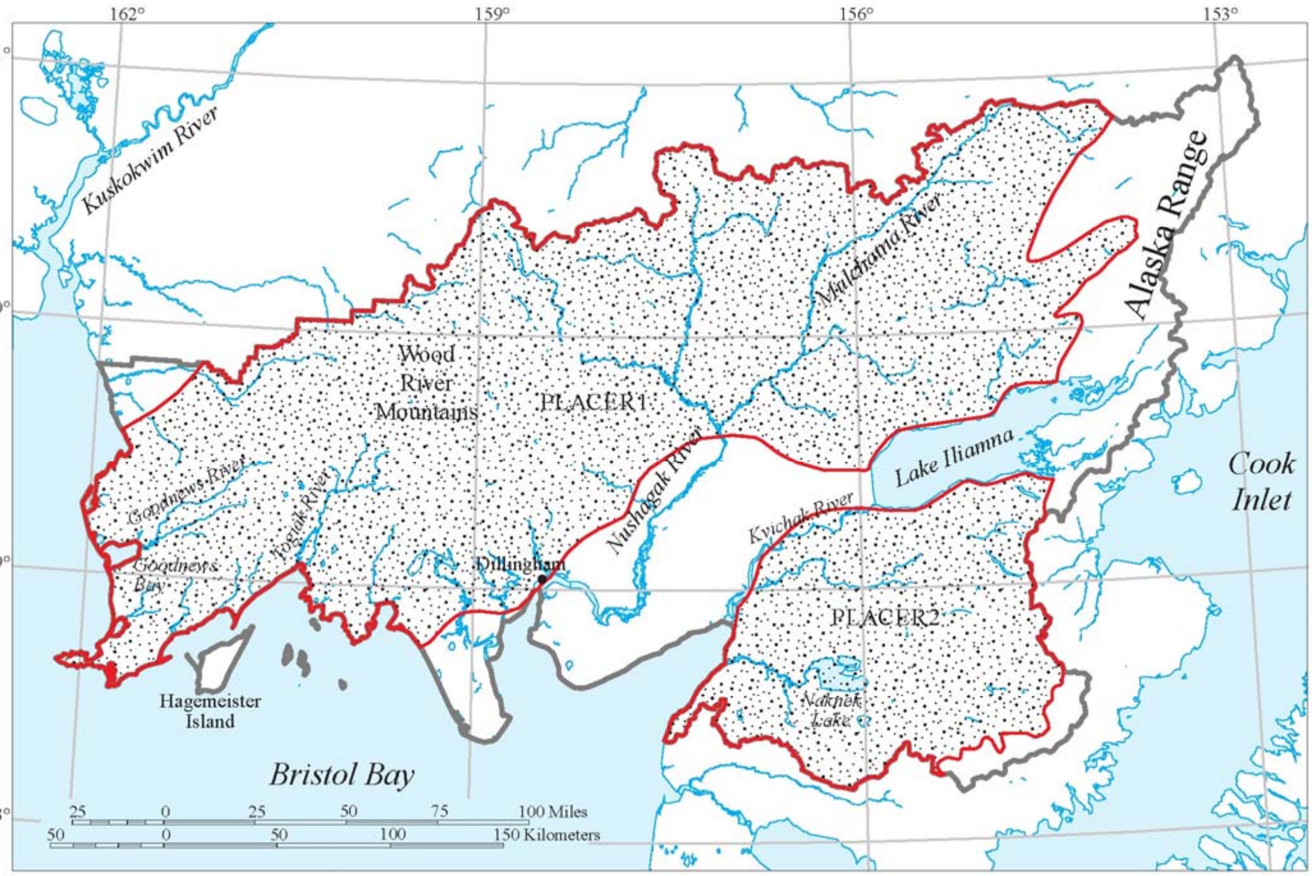

Figure 23. Location of tracts PLACER 1 and PLACER 2, delineating areas within the Bay RMP area that are permissive for placer gold deposits.

Tract PLACER2 (fig. 23) includes areas of unconsolidated deposits south of Lake Iliamna. Potential lode sources of gold within this tract are epithermal veins, porphyry copper-gold deposits, hot spring gold deposits, gold-enriched skarns, and several types of volcanogenic massive sulfide deposits. No placer gold occurrences are known from within tract PLACER2. Because it contains large areas of National Parks and Wildlife Refuges in which no significant exploration has occurred and for which there is little mineral deposit information available, no quantitative assessment of tract PLACER2 was attempted.

Quantitative Estimates

A grade and tonnage model for placer gold deposits has been defined (Orris and Bliss, 1986) but includes no Alaskan examples. The model specifically excludes "large regional placers formed at the junction of mountainous areas and an adjacent plain or valley" which are economic at lower grades than the median size in the published model. Much of the historic placer gold production in Alaska was from mountain-front regional placers, and many of the undiscovered deposits are likely to be of a similar type. The Orris and Bliss (1986) grade and tonnage model is used here for the quantitative estimates for tract PLACER1, primarily because no reliable grade tonnage information is available from historic Alaskan placer mines or districts that would be more representative of the undiscovered occurrences.

Berg and others (1964) reported that 20 million ounces of gold had been produced from placer deposits in Alaska and estimated that the remaining resources were "at least equal in quantity and grade to those that have been mined." Because of the relative ease of placer gold exploration, much of tract PLACER1 has been explored in the past. There is a relatively low probability that major new districts will be discovered, but additional placer gold deposits that have grades and tonnages similar to the published placer gold model are likely within the tract.

The number of undiscovered placer gold deposits, consistent with the tonnage and grade curves of Orris and Bliss (1986) (median 1.1 million metric tons, 0.2 gpt gold), was estimated to be 1 at the 90th percentile, 2 at the 50th percentile and 7 at the 10th percentile probability levels (table 1).

From these estimates, the EMINERS program summarizes the mean number of undiscovered placer gold deposits in tract PLACER1 to be 3.1 (table 11). Table 11 also indicates the possible amount of contained metals within the undiscovered deposits at the mean and at five probability levels. Variability in the calculated contained metal estimates is illustrated in figure 24. Cumulative probabilities of tonnage of each metal and mineralized rock are shown in figure 25.

Tract PLACER1 has a 95-percent probability of containing no gold-bearing placers of a median size and grade, a 90-percent probability of containing at least 12,000 metric tons of mineralized sediments, and a 5-percent probability of containing as much as 13 metric tons gold or one metric ton silver (table 11; figs. 24 and 25).

Placer gold deposits that have tonnages smaller than the median reflected by the grade and tonnage curves also are likely to occur within tract PLACER1. These deposits would be of a type amenable to recreational or small-scale mining with an estimated cleanup of a hundreds to a thousands of ounces of gold, rather than the >200,000 ounces of gold contained in a median sized deposit. We estimate that there may be as many as 25 of these undiscovered smaller scale placer deposits.

Table 11. Estimated amounts of contained metal and mineralized rock (metric tons) in placer gold deposits in tract PLACER1.

[EMINERS index: 80 (Placer Au 39a). Mean number of deposits = 3.1. **Abbreviations:** Au, gold; Ag, silver]

Quantile	Au	Ag	Rock
0.95	0	0	0
0.90	0	0	12,000
0.50	1	0	16,000,000
0.10	9	0.3	125,400,000
0.05	13	0.6	180,000,000
Mean	3	0.1	42,000,000
Probability of mean	0.32	0.18	0.31
Probability of zero	0.07	0.50	0.07

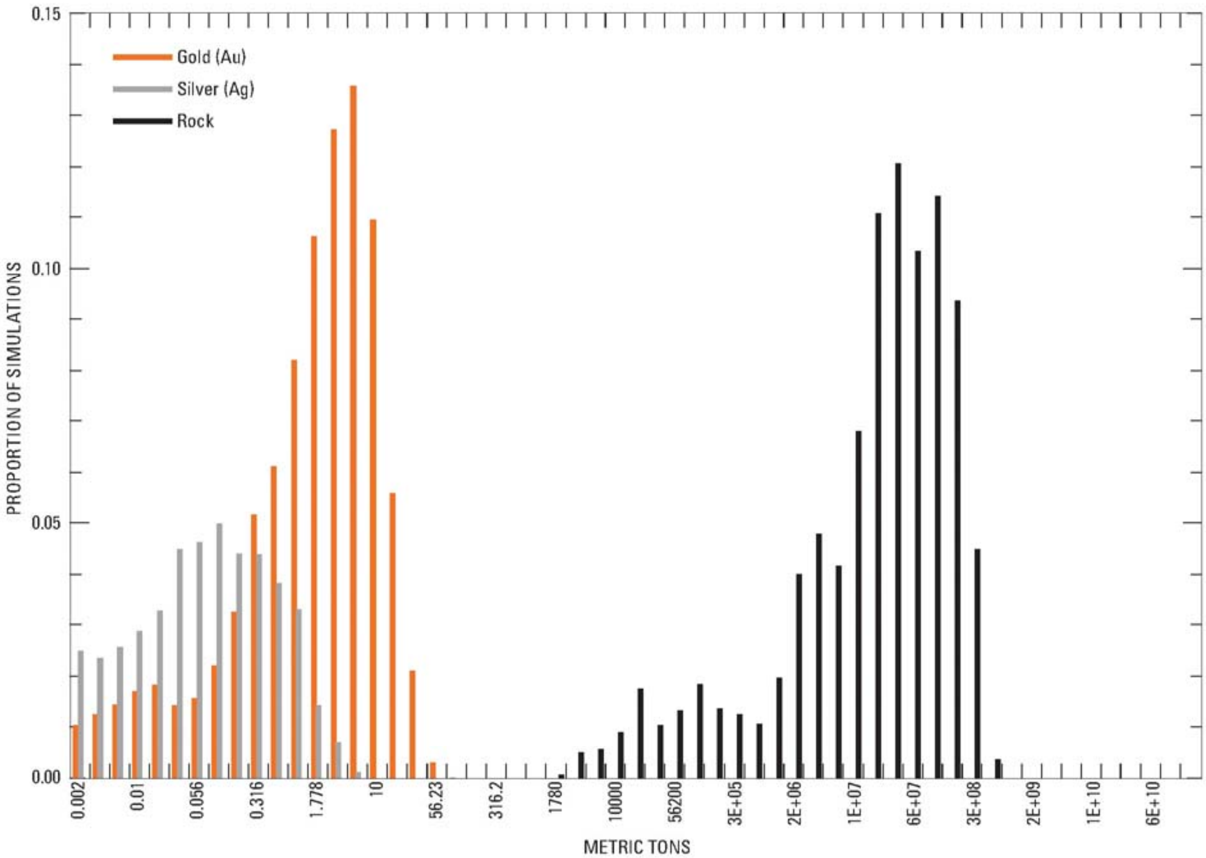

Figure 24. Contained metal and mineralized rock in placer gold deposits in tract PLACER1.

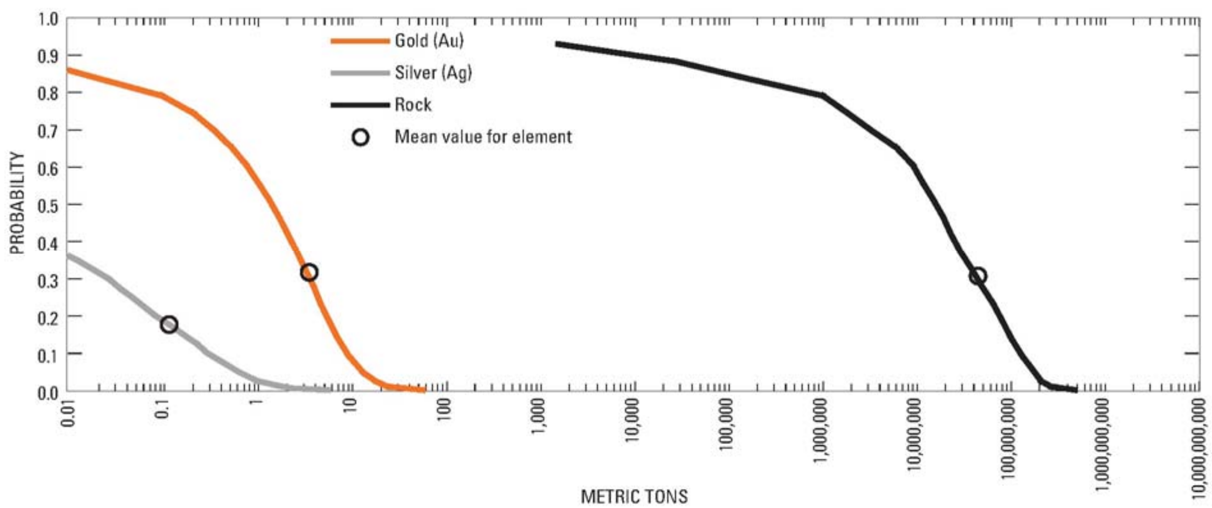

Figure 25. Cumulative distribution of contained metal and mineralized rock in placer gold deposits in tract PLACER1.

Assessment of Permissive Tracts for Deposit Models with no Quantitative Estimates

Tract Name: BESSHI

Model Name: Besshi Massive Sulfide
USGS Deposit Model: 24b
Area: 15,970 km^2

Rationale for Model Choice and Tract Delineation

The western part of the BMPA is permissive for Besshi-type sedimentary-rock-hosted massive sulfide deposits (Cox, 1986a) containing copper, zinc, silver, and gold. Tract BESSHI (fig. 26) is defined by the presence of potentially appropriate host rocks as described in the published model (terrigenous clastic rocks and volcanic rocks of mafic to intermediate composition) and by geochemical anomalies of included elements.

Tract BESSHI includes all of the Goodnews terrane and most of the Togiak terrane defined by Decker and others (1994). The heterogeneous Goodnews terrane locally includes tuff and graywacke (Hoare and Coonrad, 1978; Box and others, 1993). The Hagemeister subterrane of the Togiak terrane (Decker and others, 1994) is underlain by areas mapped as tuff, tuffaceous sedimentary rocks, graywacke, and siltstone (Hoare and Coonrad, 1978).

Stream-sediment samples from the southwestern part of the Goodnews terrane have anomalous values of copper, zinc, cobalt, chromium, and gold (Kilburn and others, 1993). Zinc and copper anomalies are found locally in the Togiak terrane (Kilburn and others, 1993). No Besshi-type deposits or prospects are known from tract BESSHI or anywhere within the BMPA.

Quantitative Information

A grade and tonnage model for Besshi massive sulfide deposits has been defined (Singer, 1986a) (median 0.22 million metric tons, 1.5 weight percent copper). However, because of inadequate geological and lithological data on potential host rocks in the area, and because no prospects of this type occur in the BMPA, no quantitative estimate of undiscovered resources was made.

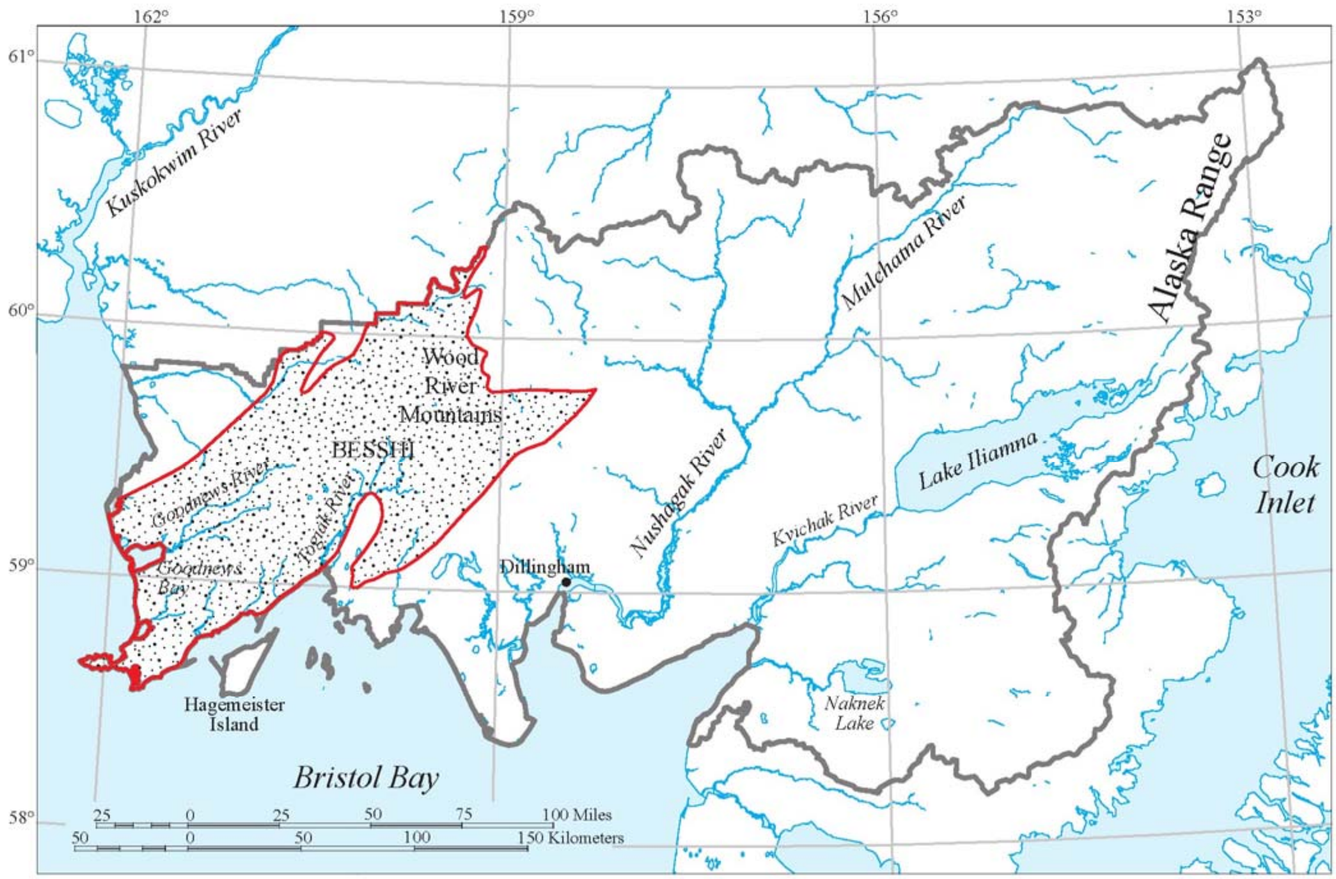

Figure 26. Location of tract BESSHI, delineating areas within the Bay RMP area that are permissive for Besshi-type massive sulfide deposits.

Tract Name: CYPRUS

Model Name: Cyprus Massive Sulfide
USGS Deposit Model: 24a
Area: 5,060 km^2

Rationale for Model Choice and Tract Delineation

The western part of the BMPA is permissive for Cyprus-type volcanogenic massive sulfide deposits (Singer, 1986b) containing copper, zinc, silver, and gold. Tract CYPRUS (fig. 27) is defined by the presence of potentially appropriate host rocks and by areas whose magnetic signatures suggest the presence of mafic rocks near the surface. Appropriate host rocks are marine mafic and metamafic rocks (greenstone) that are the basaltic, locally pillowed parts of an ophiolite sequence.

The geologic units in the Goodnews Bay and Hagemeister Island quadrangles contain scattered mafic-ultramafic complexes and associated pillow basalt and gabbro that were interpreted by Box (1985) and Patton and others (1992, 1994) as ophiolitic suites. Because the geologic information available for the area is not detailed, tract CYPRUS contains other lithologies within the ophiolite sequence, in addition to the target lavas.

Stream-sediment samples from this area are locally anomalous in cobalt, copper, chromium, and nickel (Kilburn and others, 1993). No Cyprus-type deposits or prospects are known from tract CYPRUS or within the BMPA.

Quantitative Information

A grade and tonnage model for Cyprus massive sulfide deposits has been defined (Singer and Mosier, 1986a) (median 1.6 million metric tons, 1.7 weight percent copper). However, because of inadequate geological and lithological data on potential host rocks in the area, and because no prospects of this type occur in the BMPA, no quantitative estimate of undiscovered resources was made.

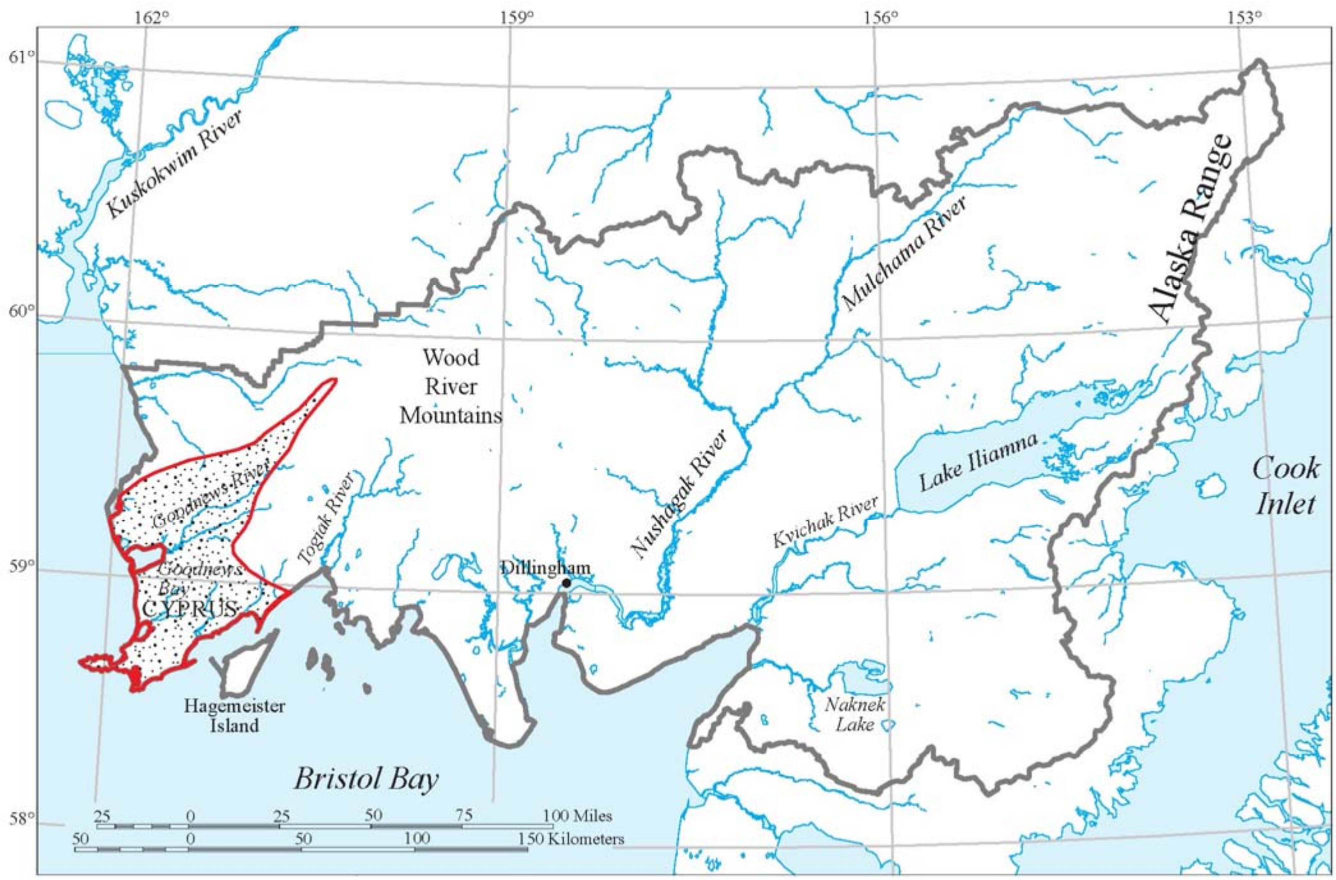

Figure 27. Location of tract CYPRUS, delineating areas within the Bay RMP area that are permissive for Cyprus-type massive sulfide deposits.

Tract Name: HSAU

Model Name: Hot Spring Gold
USGS Deposit Model: 2
Area: 43,470 km^2

Rationale for Model Choice and Tract Delineation

Hot spring gold-silver deposits (Berger, 1986a) are sinters and stockworks developed at very shallow levels (<500 m) in the crust, in extrusive and subvolcanic rhyolite. They are variably associated with some types of epithermal quartz veins or with host-spring mercury deposits and may be a lode source for gold placers.

Tract HSAU (fig. 28) is defined primarily by the presence of Tertiary volcanic and shallow intrusive rocks (Detterman and Reed, 1980; Nelson and others, 1983; Riehle and others, 1993; Wilson and others, 2003) that are permissive hosts and causative heat sources for both hot spring gold and epithermal vein deposits. The tract includes isolated gold and silver stream-sediment geochemical anomalies, and its western boundary was delineated by regional aeromagnetic data, to encompass a large magnetic domain in the southeastern part of the BMPA. This domain is characterized by abundant short-wavelength, high- amplitude magnetic anomalies, most likely caused by magnetite-bearing intrusive rocks at relatively shallow depths in the sub-surface. Tract HSAU is also characterized by high K/Th ratios where aeroradiometric data is available. The high K/Th values indicate the presence of felsic rocks, including subvolcanic and extrusive rhyolites, which may be hosts or causative intrusions for the hot spring deposits.

Placer gold occurrences in drainages west and north of Sugarloaf Mountain (Church and others, 1992) and felsic-volcanic-hosted vein occurrences such as the Sill prospect (Schrader, 2001; Hawley, 2004) suggest that this tract is permissive for the occurrence of hot spring gold veins.

Mercury deposits in southwestern Alaska are vein and subvolcanic occurrences that locally contain anomalous gold (Gray and others, 1997). They are closely associated with the shallow- to intermediate-level intrusion-related gold deposits in the area and appear to have formed at generally deeper levels (>500 m) in the crust than is typical for hot-spring gold deposits.

Quantitative Estimates

The published grade and tonnage model for hot-spring gold deposits (Berger and Singer, 1986), derived entirely from deposits in the western US, defines a median deposit of 13 million metric tons and a median grade of 1.6 gpt gold and 2.9 gpt silver.

Because of inadequate geological information on the relative proportion of rhyolite with the volcanic rocks of tract HSAU, because of the close association of gold and mercury and difficulty in assigning models appropriate to the local geology, and because no prospects of this type are known from the BMPA, no quantitative estimate of undiscovered resources was made.

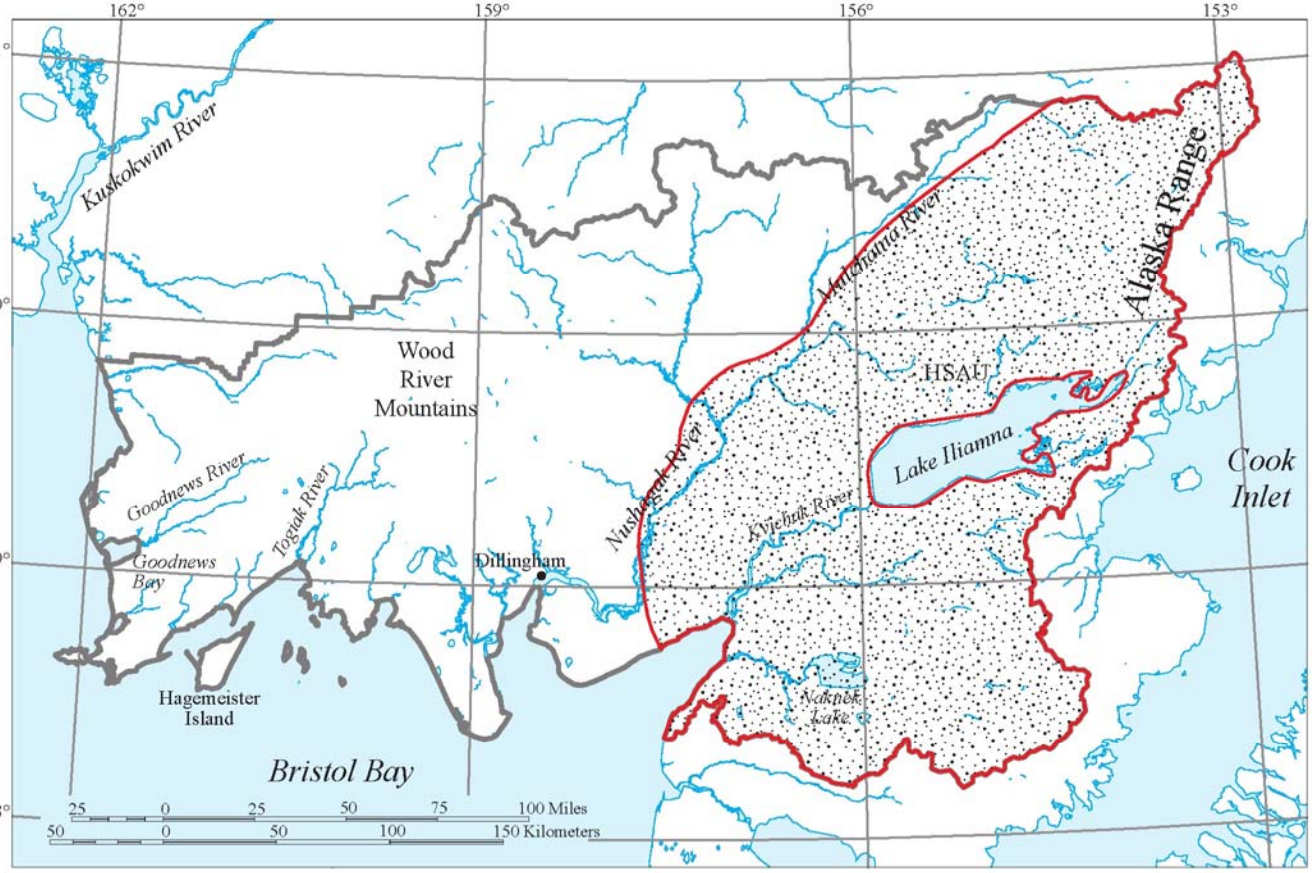

Figure 28. Location of tract HSAU, delineating areas within the Bay RMP that are permissive for hot-spring gold deposits.

Tract Names: KUROKO1 / KUROKO2

Model Name: Kuroko Massive Sulfide
USGS Deposit Model: 28a, 28a1
Area:
KUROKO1: 6,650 km^2
KUROKO2: 10,290 km^2

Rationale for Model Choice and Tract Delineation

Felsic- to intermediate-composition submarine volcanic rocks within island arc and back-arc sequences are potential host rocks for kuroko-type volcanogenic massive sulfide deposits (Singer, 1986c) in the BMPA.

Tract KUROKO1 (fig. 29) was defined by the presence of the Early Jurassic Talkeetna Formation — an island arc sequence of basaltic to andesitic marine volcanic rocks and less common felsic volcanic rocks. The volume of felsic rocks within the Talkeetna Formation is uncertain, but low. Three kuroko-type sulfide prospects are known from the Talkeetna Formation outside the BMPA (Nelson and others, 1983; Bickerstaff, 1998); none are known within tract KUROKO1.

Tract KUROKO2 (fig. 29) is defined by mixed marine volcanic and sedimentary rocks of Late Triassic to Early Cretaceous age and probable marine arc affiliation. Permissive rocks in the Bethel, Goodnews Bay, Hagemeister Island, and Dillingham quadrangles include overlap assemblages which overlie parts of the Togiak terrane, most of the Goodnews terrane, and all of the Kilbuck terrane (as defined by Decker and others, 1994). The Goodnews terrane contains only local felsic volcanic rocks in a sequence dominated by pillow basalt, intermediate to mafic flows and volcaniclastic rocks (Hoare and Coonrad, 1978; Box and others, 1993); the Hagemeister subterrane of the Togiak terrane (Decker and others, 1994) consists of marine volcanic and volcaniclastic strata, including some of intermediate and trachytic composition (Hoare and Coonrad, 1978). The volume of felsic volcanic rocks known within tract KUROKO2 is small. Stream-sediment samples from the southwestern Goodnews terrane are anomalous in copper, zinc, cobalt, chromium, and gold; zinc and copper anomalies occur locally in the Togiak terrane (Kilburn and others, 1993). No mineral occurrences of the kuroko volcanogenic massive sulfide type are known from within tract KUROKO2.

Quantitative Information

Two grade and tonnage models for kuroko massive sulfide deposits have been defined. Singer and Mosier (1986b) defined a worldwide median of 1.5 million metric tons, 1.3 weight percent copper, 2.0 weight percent zinc, 0.16 gpt gold, and 13 gpt silver. Using only Alaskan and western North American deposits of Triassic to Jurassic age (median 0.31 million metric tons, 1.4 weight percent copper, 2.9 weight percent zinc, 1.3 gpt gold, 32 gpt silver), Singer (1992) defined a subset of smaller deposits, which contain higher precious metal values. This latter grade and tonnage model would be the appropriate choice for estimating the potential for kuroko-type deposits within the BMPA.

However, the volume of intermediate to felsic-composition rocks is low relative to basaltic to andesitic rocks in the Talkeetna Formation (tract KUROKO1) and very low in the arc sequences that make up tract KUROKO2. Therefore, the probability of undiscovered kuroko massive sulfide deposits is correspondingly low. However, because of inadequate geological and lithological data to evaluate the characteristics of potential volcanic host rocks in the area and because no prospects of this type occur in the BMPA, no quantitative estimate of undiscovered resources was made.

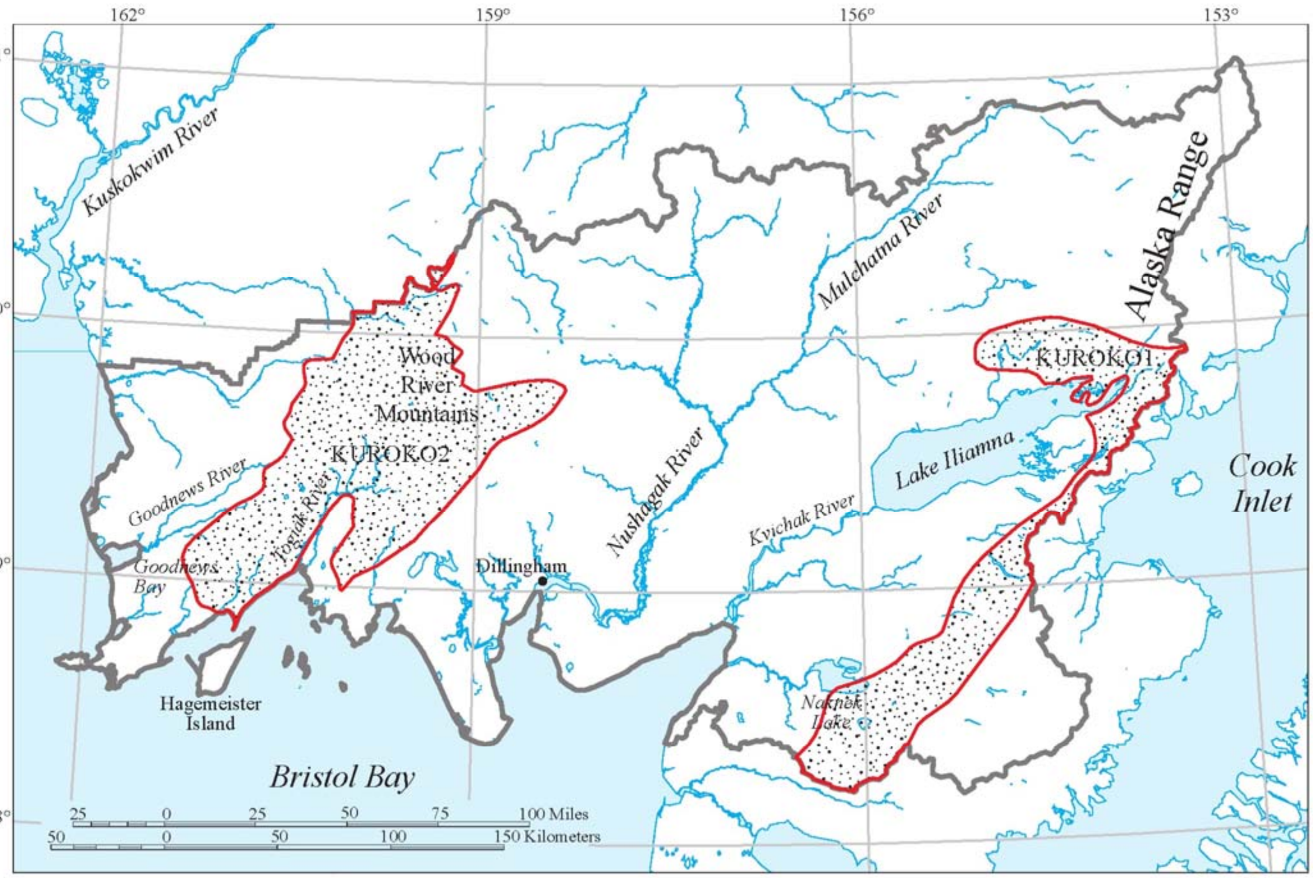

Figure 29. Location of tracts KUROKO1 and KUROKO2, delineating areas within the Bay RMP area that are permissive for Kuroko-type massive sulfide deposits.

Tract Name: LOSAU

Model Name: Low Sulfide Gold-Quartz Veins
USGS Deposit Model: 36a, 36a.1
Area: 6,600 km^2

Rationale for Model Choice and Tract Delineation

Low-sulfide (also called orogenic-, mesothermal- or Mother-Lode-type) gold-quartz veins (Berger, 1986b) are large, anastomosing, laterally persistent vein systems, which often occur along regional faults and in response to moderate- to high-grade regional metamorphism. They contain native gold, minor base metal sulfide minerals, and carbonate-dominant alteration. Low-sulfide gold-quartz veins are permissive in the BMPA in mixed oceanic lithologies that show evidence for greenschist or higher facies metamorphism.

Tract LOSAU (fig. 30) is defined as a belt extending from the Bethel quadrangle through the Goodnews and Hagemeister Island quadrangles. It includes mafic and felsic schist of the Kilbuck terrane and part of the Goodnews terrane, which includes mudstone, basalt, serpentinite, ophiolitic rocks, and schist. Metamorphic grade in the Goodnews terrane is prehnite-pumpellyite to low greenschist facies; Kilbuck terrane rocks reached greenschist or higher facies (Dusel-Bacon and others, 1996). Geologic units within tract LOSAU are structurally complex (Hoare and Coonrad, 1978; Decker and others, 1994), making evaluation of potential and exploration for deposits difficult.

No deposits of the low-sulfide gold-quartz vein type are known within tract LOSAU. The Arnold prospect in the Russian Mission quadrangle, outside the BMPA (Hudson and Milholland, 2002), however, is probably a low-sulfide gold-quartz vein deposit. The presence of placer gold in tract LOSAU (Hudson, 2001c), south of the Kilbuck terrane, in areas of metamorphosed bedrock lithologies is consistent with the model designation (Berger, 1986b).

Quantitative Information

Two grade and tonnage models for low-sulfide gold-quartz vein deposits have been defined. Bliss (1986) defined a worldwide median of 0.03 million metric tons and 16 gpt gold. A second model having lower tonnages and grades was later developed for vein deposits in the Chugach Mountains of southern Alaska (Bliss, 1992) (median 0.0032 metric tons, 6.2 gpt gold). This latter grade and tonnage model would be the appropriate choice to estimate the potential for low sulfide gold-quartz deposits within tract LOSAU.

Because of an inadequate understanding of the thermal history and geological setting of potential host rocks in the BMPA and because no low-sulfide gold vein prospects are known, no quantitative estimate of undiscovered resources was made.

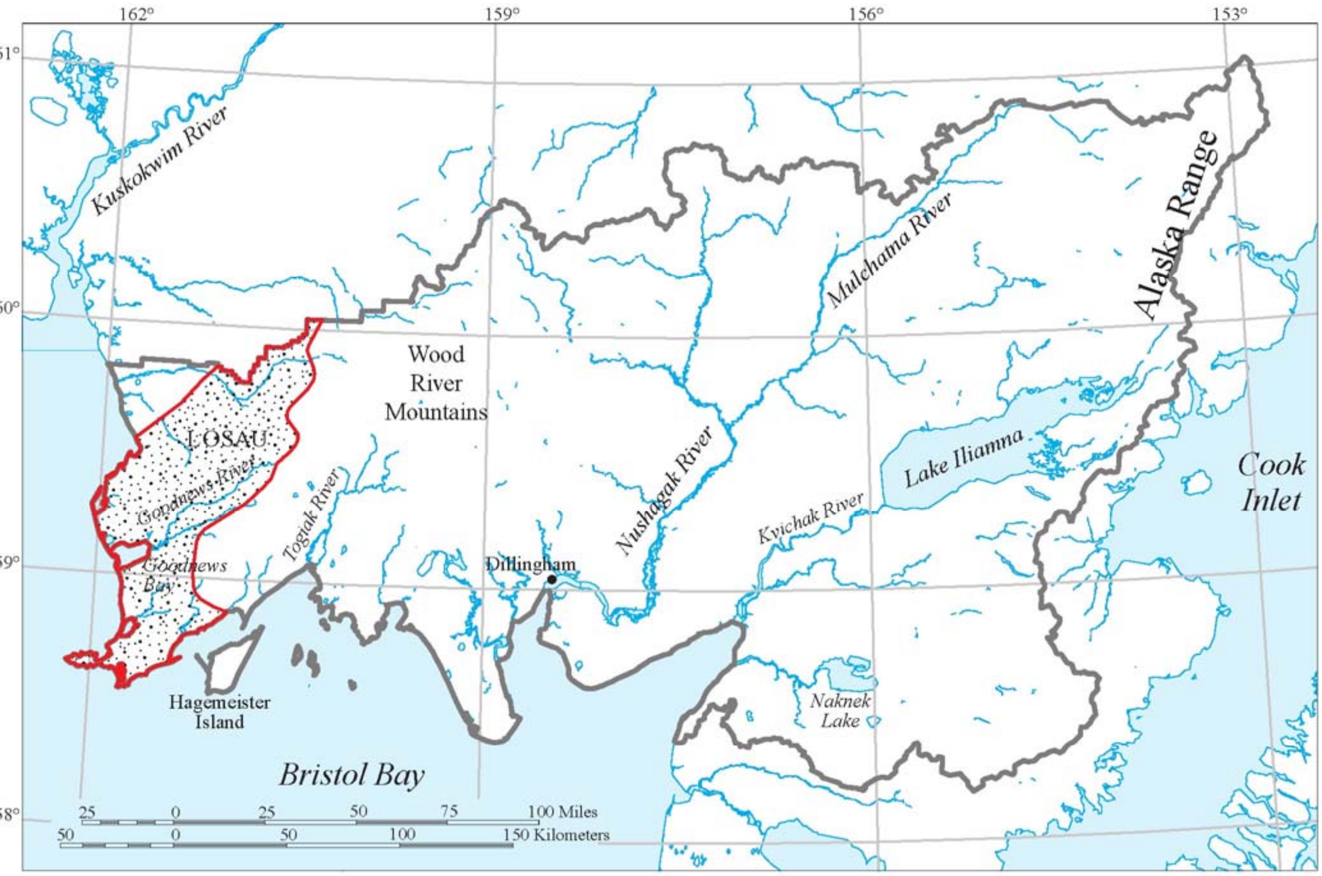

Figure 30. Location of tract LOSAU, delineating areas within the Bay RMP area that are permissive for low sulfide gold quartz vein deposits.

Tract Name: MVT

Model Name: Mississippi Valley Lead-Zinc
(Also applicable to Kipushi copper-lead-zinc)
USGS Deposit Model: 32a, b, c
Area: 1,720 km^2

Rationale for Model Choice and Tract Delineation

Shallow-water carbonate rocks and lithostratigraphic units containing carbonate rocks in the southwestern part of the BMPA are permissive for Mississippi Valley type and/or Kipushi-type base metal deposits.

Two descriptive Mississippi Valley type (MVT) deposit models have been published. The southeast Missouri lead-zinc (model 32a; Briskey 1986b) and Appalachian zinc (model 32b; Briskey, 1986a) deposit models differ somewhat in ore mineralogy, alteration mineralogy, and metal content, but both consist of epigenetic replacement bodies within shallow-water carbonate rocks. In Alaska, the lack of detailed geologic information prevents determining which, if either, of the two deposit model sub-types would be appropriately applied. Therefore, we have used a generic Mississippi Valley type lead-zinc model to delineate permissive tracts in the BMPA.

Kipushi copper-lead-zinc deposits (model 32c; Cox and Bernstein, 1986) are stockwork and replacement deposits that are similar to MVTs in host rock lithology, formation, and style but contain a different copper-enriched metal suite. Although carbonate rocks within the BMPA are permissive for Kipushi-type deposits, this model will not be considered further here because of its rarity worldwide and the poor understanding of what geologic conditions account for the formation of deposits of this type.

Tract MVT (fig. 31) is defined by geologic units that contain blocks of Ordovician, Devonian, and Permian limestone. These blocks constitute less than 5 percent of a structurally disrupted unit of mixed marine sedimentary and volcanic rock that forms the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). The limestone blocks show algal reef and reef breccia textures (Hoare and Coonrad, 1978) that suggest a depositional environment appropriate for potential host rocks to Mississippi Valley type deposits.

No MVT occurrences are known from within tract MVT. However, possibly correlative rocks in west-central Alaska host several stratabound zinc deposits (for example, Reef Ridge district) that probably are of the MVT (and possibly the Appalachian zinc) type (Schmidt, 1997; Bundtzen, 1999b).

Quantitative Information

The grade and tonnage model defined for Mississippi Valley type deposits (Mosier and Briskey, 1986) (median 35 million metric tons, 4.0 weight percent zinc, 0.87 weight percent lead, 0.5 gpt silver) combines information from deposits of both the Appalachian zinc and Southeast Missouri lead-zinc descriptive subtypes. Because of the limited areal extent of carbonate rocks within tract MVT, the lack of known occurrences within the BMPA, and inadequate geological and lithological data to evaluate the characteristics of potential host rocks in the area, no estimate of undiscovered resources was made.

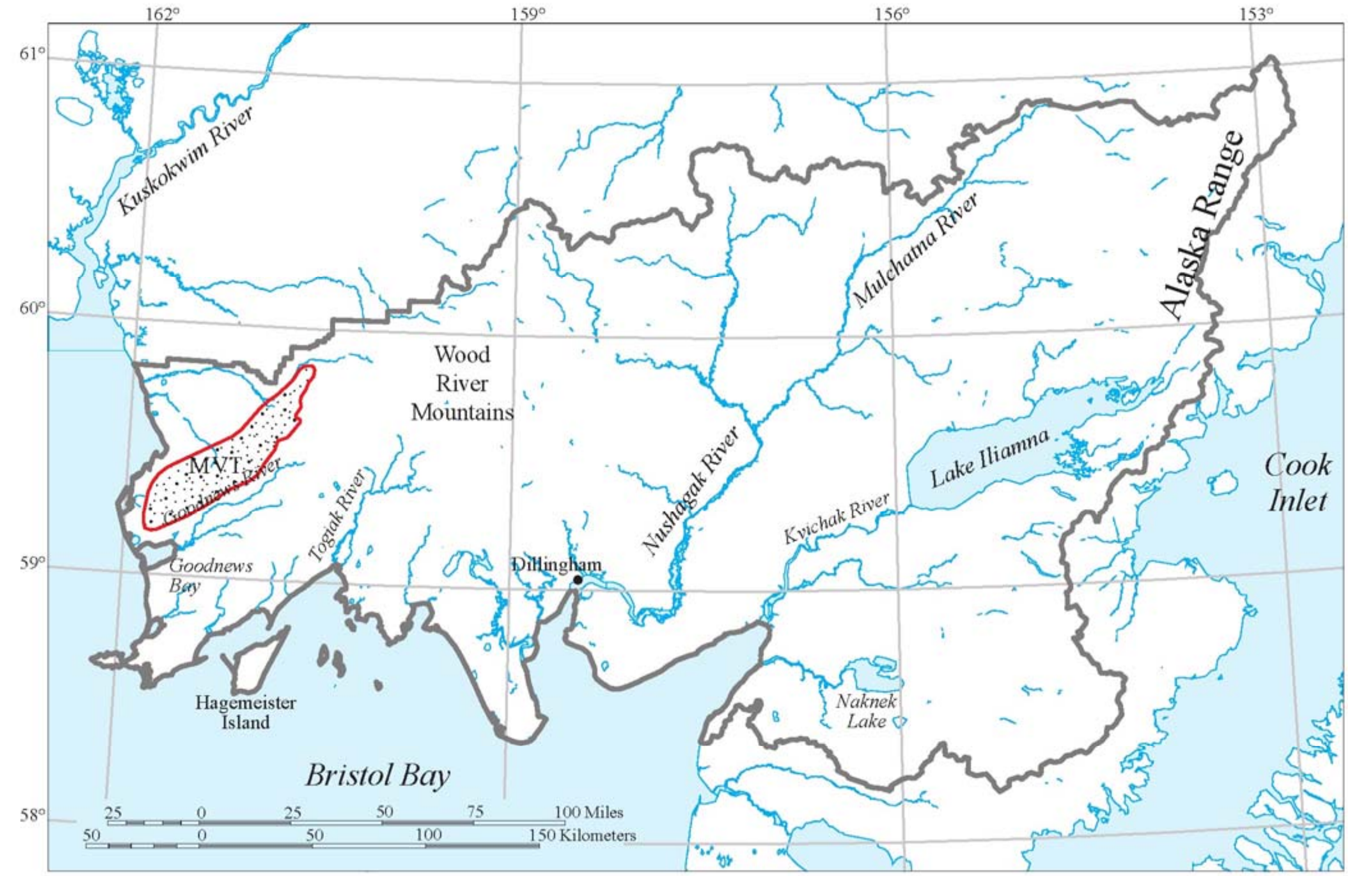

Figure 31. Location of tract MVT, delineating areas within the Bay RMP area that are permissive for Mississippi Valley type lead-zinc deposits.

Tract Name: SNG

Model Name: Tin Greisen
USGS Deposit Model: 15c
Area: 36,120 km^2

Rationale for Model Choice and Tract Delineation

Tin greisen deposits comprise stockworks and disseminations within the cupolas of magmatic-vapor altered "specialized" or high-silica granites. The deposits are characterized by muscovite, tourmaline, topaz, and fluorite alteration minerals; associated elements are lithium, tungsten, molybdenum, silver, and boron (Reed, 1986). Tin greisen deposits are permissive in the BMPA because of the presence of Cretaceous and/or Tertiary granitic rocks; geochemical affinities of these rocks are generally poorly known.

Tract SNG (fig. 32) is defined by the maximum known extent of early Tertiary granitic intrusions and by the location of known tin prospects. Host rocks to the intrusions are predominantly clastic sedimentary rocks of the Cretaceous Kuskokwim Group and Kahiltna flysch.

The Sleitat tin prospect (Burleigh, 1991; Farnstrom, 1991; Hudson, 2001e), in the central BMPA, in tract SNG, has been described as a sheeted greisen deposit. At Sleitat a 60 Ma composite granite stock produced a significant hornfels aureole in Cretaceous Kuskokwim Group sedimentary rocks. Quartz-topaz-tourmaline-cassiterite veins in the stock are estimated to host a resource of 26 million metric tons of 0.2 to 0.4 weight percent tin (Burleigh, 1991). Elevated tungsten and silver values at Sleitat are consistent with the tin greisen grade and tonnage model of Menzie and Reed (1986).

Quantitative Information

A grade and tonnage model for tin greisen deposits has been defined (Menzie and Reed, 1986) (median 7.2 million metric tons, 0.28 weight percent tin). Typical deposit densities suggest that undiscovered greisen deposits should occur near the Sleitat occurrence within the BPMA. However, the geologic information available is inadequate to separate potential host suites of specialized (that is, high silica, high volatile) granite character from all other Cretaceous to Tertiary granitic rock suites in the region. Tin geochemical analyses are not available for much of the BMPA, and because of this scarcity of data, no quantitative estimate of undiscovered resources was made.

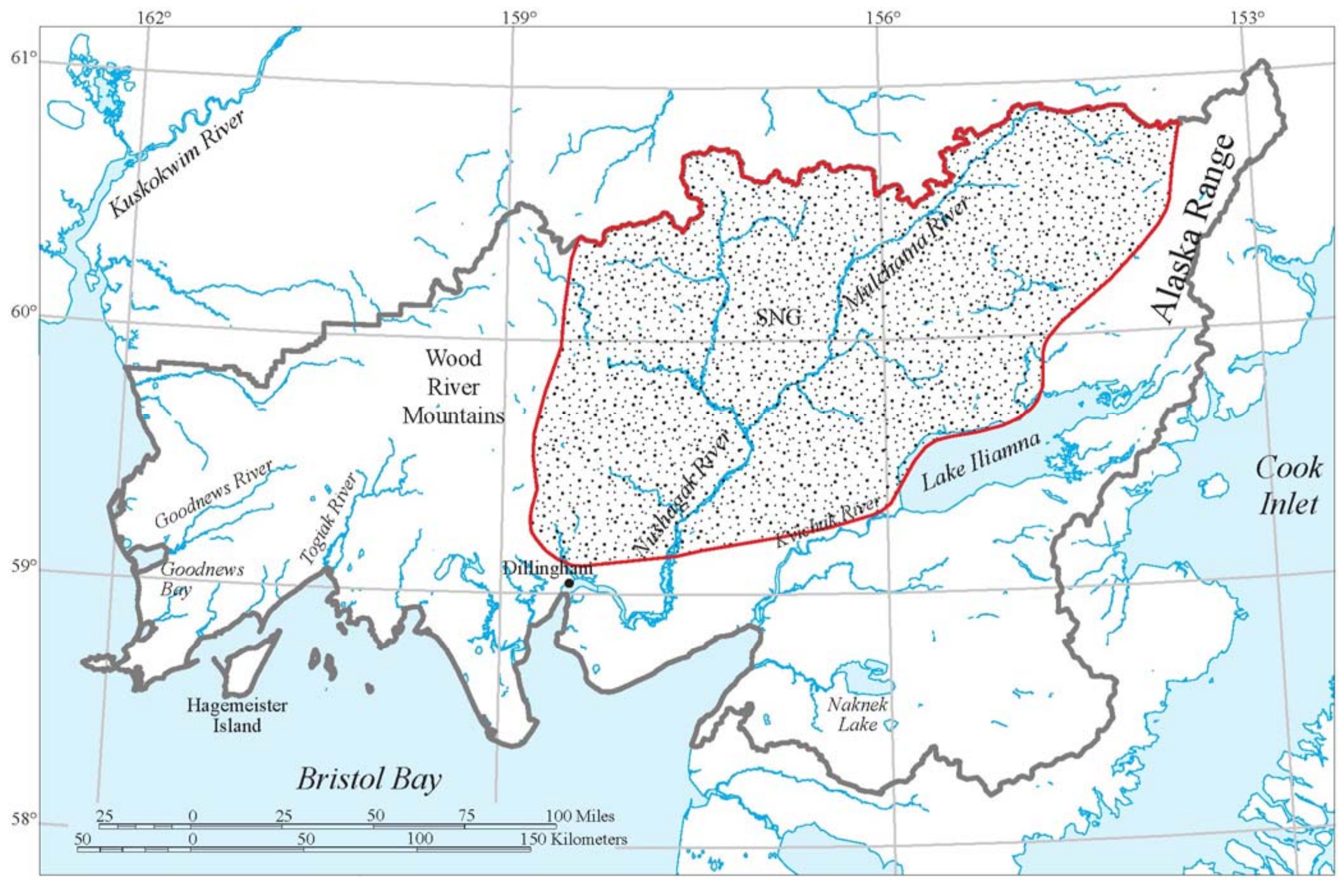

Figure 32. Location of tract SNG, delineating areas within the Bay RMP area that are permissive for tin greisen deposits.

Tract Names: ZNSK1 / ZNSK2

Model Name: Zinc (Lead) Skarn
USGS Deposit Model: 18c
Area: CUSK 1: 11,020 km^2
CUSK 2: 1,950 km^2

Rationale for Model Choice and Tract Delineation

Carbonate rocks and carbonate rock-bearing lithostratigraphic units that have been intruded by Jurassic, Cretaceous, and/or Tertiary plutons, may host zinc (lead) skarn deposits that fit the model of Cox (1986e).

Permissive tract ZNSK1 (fig. 33) is identical to tracts CUSK1 and FESK1 (figs. 5 and 11) and is defined by the presence of Triassic limestones of the Kamishak Formation (Detterman and Reed, 1980; Decker and others, 1994), which crop out in areas intruded by Jurassic, Cretaceous, and Tertiary plutons of the Alaska-Aleutian Range batholith. Where aeroradiometric data are available, tract ZNSK1 is characterized by high K/Th ratios, which indicate the presence of felsic rocks, including granitic plutons associated with development of skarn mineralization. Tract ZNSK1 also contains carbonate-rock bearing roof pendants of unknown, but probable Triassic, age, intruded by stocks in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980). Numerous small copper skarns, and a few small calcic iron (copper-gold) skarns, are reported in carbonate rocks in roof pendants in the northern Aleutian Range in the general area of tract ZNSK1 (Newberry and others, 1997; Bickerstaff, 1998; Hawley, 2004). Some prospects north of the BMPA, such as Bowser Creek and Tin Creek, have been interpreted as silver-rich zinc-lead skarns (Bundtzen, 1999a); none are known to occur in tract ZNSK1.

Permissive tract ZNSK2 is defined by areas that include blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978) that are part of the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). Late Cretaceous and early Tertiary granitic plutons occur within the Nukluk subterrane in this area, but none are known to intrude limestone. Tract ZNSK2 includes no known skarn prospects or occurrences.

Quantitative Estimates

A grade and tonnage model for zinc-lead skarn deposits has been defined (Mosier, 1986) (median 1.4 million metric tons, 5.9% zinc, 2.8% lead, 58 gpt silver). However, because of the lack of known zinc skarn occurrences within the tracts, differences in the geologic setting between tract ZNSK1 and the known zinc skarns to the north, and the limited areal extent of carbonate rocks within tracts ZNSK1 and ZNSK2, no estimate of undiscovered resources was made.

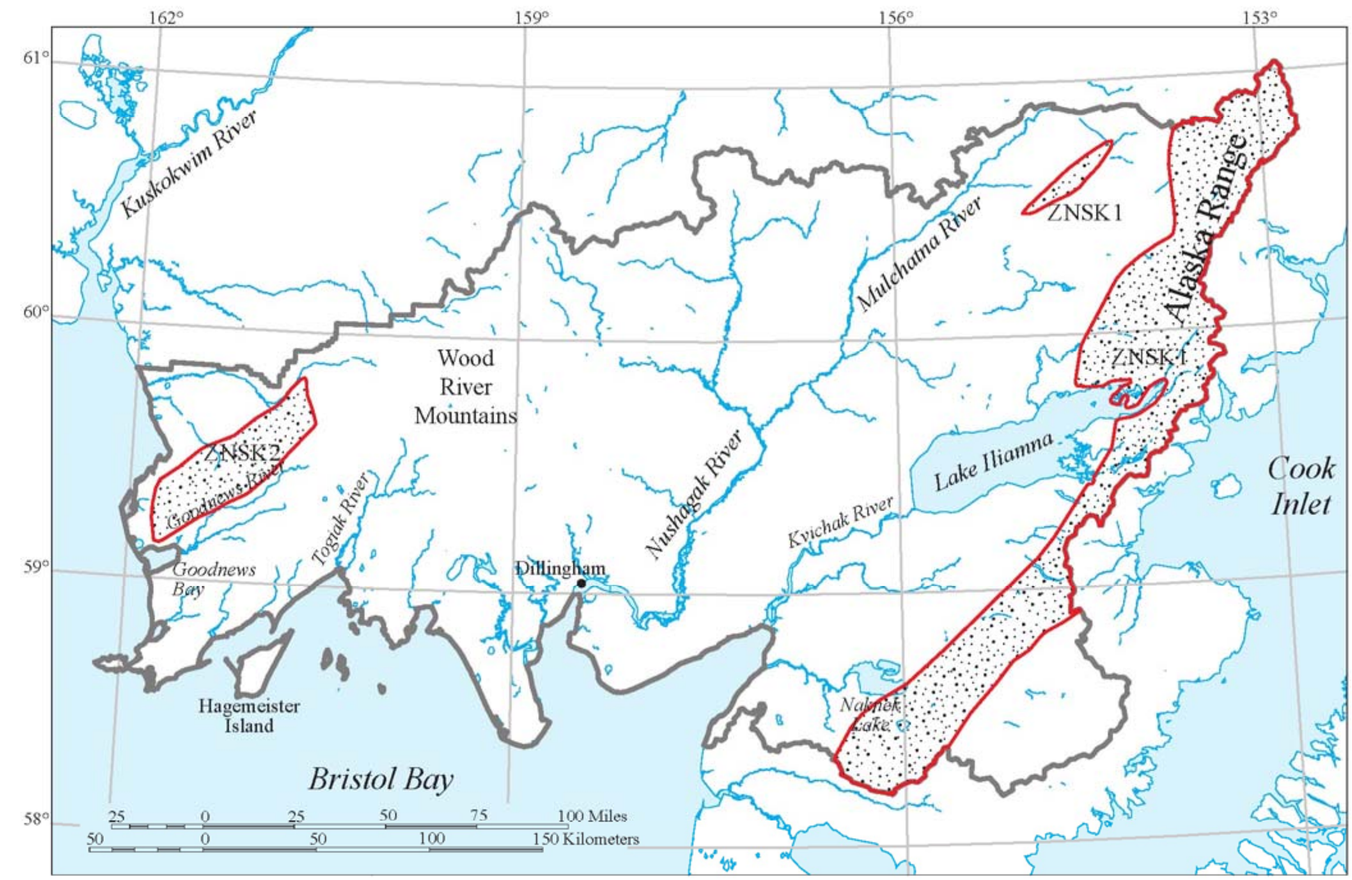

Figure 33. Location of tracts ZNSK1 and ZNSK2, delineating areas within the Bay RMP area that are permissive for zinc skarn deposits.

Tract Names: ZUM1 / 2 / 3

Model Name: Alaskan (Zoned Ultramafic Complex) PGE
USGS Deposit model: 9
Area:
ZUM1: 6,600 km^2
ZUM2: 2,720 km^2
ZUM3: 900 km^2

Rationale for Model Choice and Tract Delineation

High values of platinum group elements (PGEs) in the presence of oxide or sulfide minerals characterize zoned Alaskan-type zoned mafic-ultramafic complexes. PGEs are associated with chromite in dunite (Bird and Clark, 1976; Southworth and Foley, 1986), with magnetite in clinopyroxenite (Retherford, 2001; Van Treeck, 2003), or with pyrrhotite and chalcopyrite (Quaterra Resources, Inc., 2005) in clinopyroxenite.

Descriptive models of these PGE deposits (Page and Gray, 1986; Nixon, 1996) suggest that they are primarily magmatic, although some mineralization (Van Treeck and Newberry, 2003) has a high-temperature hydrothermal (late magmatic?) component. Lode deposits are rare and poorly understood but form the primary source of PGEs for extensively exploited PGE placers (for example, Urals, British Columbia, etc.)

Several areas of the BMPA are permissive for lode platinum-group-element (± chromium ± iron) deposits hosted in Alaskan-type zoned ultramafic complexes. Tract ZUM1 (fig. 34) is defined on the presence of appropriate host rocks. It includes all mapped mafic-ultramafic complexes in the Goodnews Bay and Hagemeister Island quadrangles; some of these have been previously interpreted as part of an ophiolite suite (Patton and others, 1992, 1994). Tract ZUM1 also includes areas whose magnetic signatures suggest the presence of mafic or ultramafic rocks near the surface. Tract ZUM2 (fig. 34) was defined based on the aeromagnetic signature of the Kemuk iron-PGE prospect (Hudson 2001b; Retherford, 2001), where subsurface ultramafic rocks have been identified. Tract ZUM2 includes plutons and stocks that have aeromagnetic signatures (an extreme high surrounded by a ring-like extreme low) similar to that overlying Kemuk. Tract ZUM3 (fig. 34) outlines areas with aeromagnetic signatures similar to those of ZUM2 but for which there are no known associated plutonic rocks.

The Goodnews Bay mafic-ultramafic complex is a zoned Alaskan-type intrusion that exhibits well-developed concentric zoning (Bird and Clark, 1976; Southworth, 1986) from a dunite core outward to clinopyroxenite and then to hornblende pegmatite. This complex, located in tract ZUM1, was the source for the platinum group elements in the Goodnews Bay placer deposits (Cobb, 1973; Foley and others, 1997), which also yielded 933 kg gold (Yeend and others, 1987) in a gold /PGE ratio of approximately 1:10 in the concentrates (Southworth and Foley, 1986). Lode PGE sources that reach minable grades have not been identified, but PGE values are elevated in rocks that contain chromite and lesser magnetite in the dunitic core (Southworth and Foley, 1986). The Kemuk prospect (in tract ZUM2) includes clinopyroxenite, wehrlitic peridotite, and hornblende gabbro characteristic of Alaskan-type complexes and contains titaniferous magnetite and anomalous values of PGEs (Hudson, 2001b; Retherford, 2001).

Quantitative Information

No grade and tonnage model is currently available for Alaskan-type PGE deposits. Although placers derived from Alaskan-type zoned ultramafic complexes have been mined in other parts of the world (Foley and others, 1997), lode sources of PGEs related to these complexes have rarely been mined or thoroughly evaluated. The mafic-ultramafic complexes at Goodnews Bay and Susie Mountain yielded mean grades of 34 ppb palladium, 47 ppb platinum and highly variable gold from 102 rocks samples (Southworth and Foley, 1986).

No estimate of undiscovered resources was made for tracts ZUM1, ZUM2, or ZUM3 because of the lack of reliable grade and tonnage data and the inadequate geological and lithological data on potential host rocks in the area.

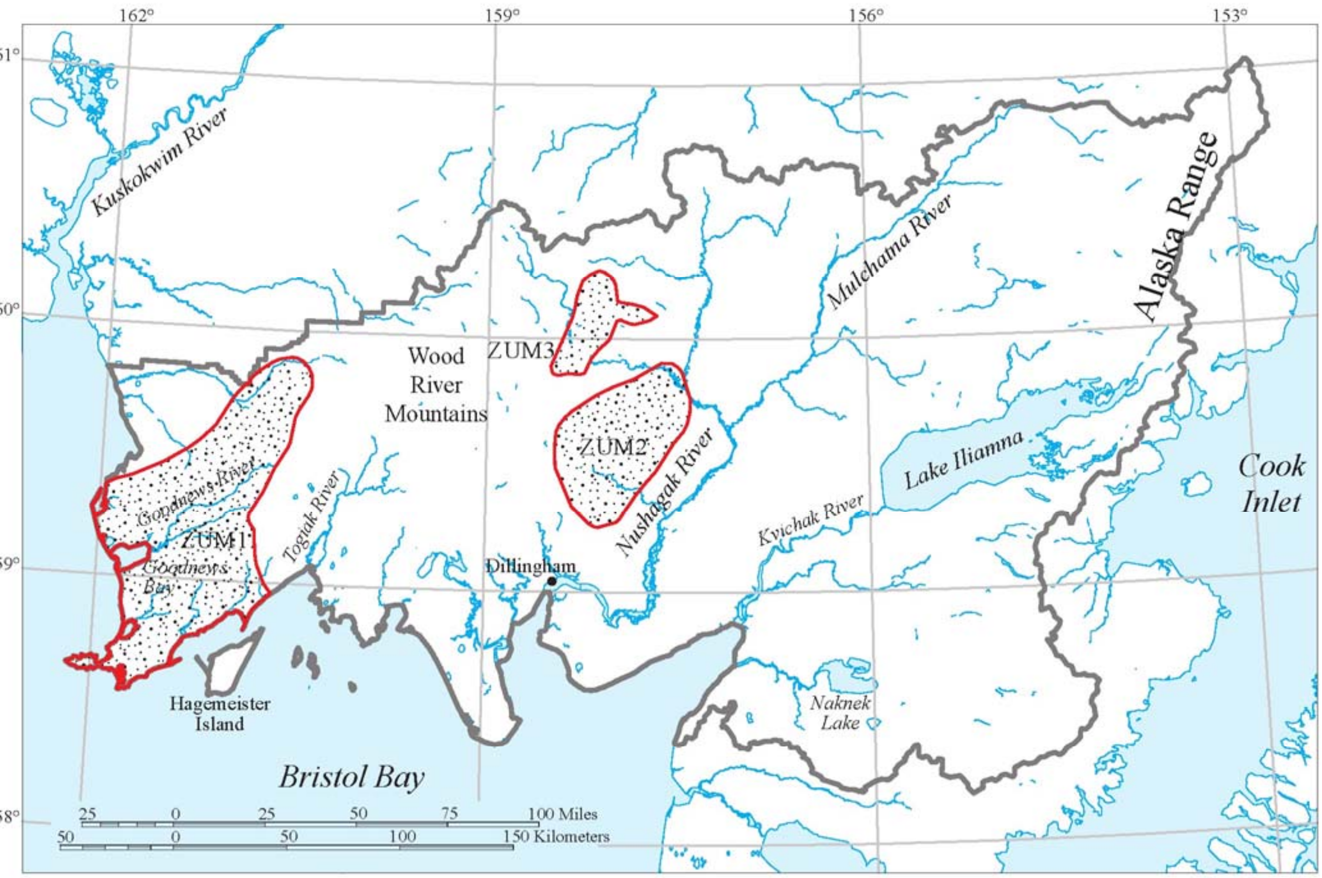

Figure 34. Location of tracts ZUM1, ZUM2, and ZUM3, delineating areas within the Bay RMP area that are permissive for Alaskan (zoned ultramafic complex) platinum-group-element deposits.

Summary

The (Bristol) Bay Resource Management Plan area in southwestern Alaska contains significant potential for base and precious metals, in addition to metallic mineral deposits already known. A probabilistic assessment of undiscovered locatable mineral resource potential within the BMPA identified seventeen different mineral deposit models as prospective for exploration or development within the next fifteen years. Twenty-four tracts outlining permissive areas were delineated within the BMPA. Quantitative estimates of the number of undiscovered deposits at three probability levels were made for porphyry copper, epithermal vein, copper skarn, iron skarn, hot-spring mercury, placer gold, placer platinum, and shallow to intermediate intrusion-related gold deposits in eight of those permissive tracts. The number of tracts quantified was limited to those with sufficient geoscience information available to adequately characterize the potential resources. The estimate for intrusion-related gold deposits comprises only deposits emplaced at shallow to intermediate depths in the crust as described in published models and current literature. In the absence of a published grade and tonnage model, the most current grade and tonnage data available from 13 deposits of this type worldwide were used to provide the probabilistic estimate of undiscovered deposits.

Significant resources of Ag, Au, Cu, Fe, Hg, Mo, Pb, and Pt are estimated to occur in the Bay Management Plan area in the eight tracts described above. At the 10^{th} percentile probability level, the BMPA is estimated to contain 10,067 metric tons silver, 1,485 metric tons gold, 12.66 million metric tons copper, 560 million metric tons iron, 8,100 metric tons mercury, 500,000 metric tons molybdenum, 150 metric tons lead, and 17 metric tons of platinum in undiscovered deposits of the eight quantified deposit types. At the 90^{th} percentile probability level, the BMPA is estimated to contain 89 metric tons silver, 14 metric tons gold, 911,215 metric tons copper, 330,000 metric tons iron, 1 metric ton mercury, 8,600 metric tons molybdenum, and 1 metric ton platinum in the eight deposit types. Additional resources of copper, iron, and gold in skarn and placer deposits may occur in the three permissive tracts that were not subject to quantitative assessment.

Other commodities that may occur in the BMPA include Cr, Sn, W, Zn, and platinum-group elements such as Ir, Os, and Pd. Thirteen of the permissive tracts outlined have potential for nine additional deposit model types. These are Besshi and Cyprus, and Kuroko-volcanogenic massive sulfides, hot spring gold, low-sulfide gold veins, Mississippi Valley Pb-Zn, tin greisen, zinc skarn and Alaskan-type zoned ultramafic platinum-group element deposits. Resources in undiscovered deposits of these nine types have not been quantified and would be in addition to those in known deposits and to the estimated undiscovered resources listed above. Additional mineral resources also may occur in the Bay RMP area in deposit types that were not considered here. These may include commodities whose demand is increasing over time, deposit models unlikely to be explored for or developed within a 15-year period, or deposit types not yet fully understood or developed into coherent models.

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